VOCATIONAL SERIES

THINGS BOYS LIKE TO MAKE

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PART I

CARPENTRY AND WOODWORK

BY PROF. EDWIN W. FOSTER

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PART I—CARPENTRY AND WOODWORK
by Prof. Edwin W. Foster

PART II—ELECTRICITY AND ITS EVERYDAY USES
by Prof. John F. Woodhull, Ph.D.

THINGS GIRLS LIKE TO DO

PART I—HOUSEKEEPING
by Elizabeth Hale Gilman

PART II—NEEDLECRAFT
by Effie Archer Archer

Drawing by J. Hodson Redman

Harold Sending the C. Q. D. Message

(*See last chapter*)

THINGS BOYS LIKE TO MAKE

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PREFACE

There is a period in a boy's life, roughly speaking between the ages of ten and sixteen, when his interests and energy turn in the direction of making things. It may be called the creative period, and with many of us it ends nearer sixty than sixteen. At one time it will take the form of a mania for building boats; again it may be automobiles or aeroplanes.

The boy is very susceptible to suggestion. A great automobile race occurs, and for weeks the building and racing of toy automobiles goes on apace. The papers are filled with accounts of an aero meet. Immediately the boy's energy turns to the study and manufacture of aeroplanes. This abounding interest in the real things of life is perfectly normal and should be encouraged rather than discouraged; but the boy needs guidance, if this energy is to be properly directed. He needs strengthening in his weak points, otherwise he may become superficial and "scattering" in his work, and fail to stick to a thing until, overcoming all obstacles, he succeeds in doing the one thing he set out to do. He may

acquire the bad habit of never finishing anything, though continually starting new schemes.

The ability of the average boy is far beyond the general estimate, but intelligent supervision is needed. The pocket knife is his natural tool, yet not one boy out of a thousand realizes its possibilities. An attempt has been made in this volume to suggest some of these, especially for boys living in the city, where a little work shop for himself, unfortunately, is too often a luxury.

The two boys here depicted form a composite picture of several thousand American boys whom it has been the pleasure of the author to guide.

The ability to design new things, and to adapt general rules to personal requirements, is to be encouraged at all times, and this idea has been exemplified in the following pages.

CONTENTS

CONTENTS

ILLUSTRATIONS

CARPENTRY AND WOODWORK

I

INTRODUCTORY

TWO boys sat on a log whittling. Conversation had ceased and they both seemed absorbed in their work. Presently the younger one became aware of the silence and glanced at the older boy. He gave an exclamation and jumped to his feet. "Why," he cried, "you are making a knife out of wood. Isn't it a beauty! Is it a dagger?"

"No" replied the other, "it is a paper-knife for opening letters and cutting the pages of magazines. It is for father's desk, for his birthday."

"It's a dandy!" continued the youngster. "How can you make such fine things? Why can't I do that kind of work?"

"You can do it," replied Ralph, "but just now there are several reasons why you don't."

"What are they?"

"Well, in the first place you start to whittle without having any clear idea of what you are at work on. It's for all the world like setting out to walk without knowing where you are going. If

you start that way, the probabilities are that you will get nowhere, and when you get back and father asks where you have been, you say, 'Oh, nowhere; just took a walk.' That's the way with your knife work. You just whittle and make a lot of chips, and when you get through you have nothing to show for your time and labour. If you want to know a secret — I never start to cut without first making a careful sketch of just what I want to make, with all the important dimensions on it.

"Another reason you don't get any results is that you don't know how to hold your knife, and still another is that you work with a dull tool. Why, that knife of yours is hardly sharp enough to cut butter."

"Will you show me how to do that kind of work?" asked the youngster humbly.

"Yes; on certain conditions."

"What are they?"

"That you will do just as I tell you."

"Will you show me how to make a paper-cutter now?"

"There you go, right off the handle! You are like a young man learning carpentry; you want to start right in to build a house instead of first learning how to use your tools. Why, it has taken me two years in the manual training school to learn how

to do this work. No, indeed, if you want to learn how to do woodwork like this you must begin on something simple, learn how to handle wood, and how to keep your tools sharp."

"All right," sighed the younger boy; "I am willing to take lessons and begin at the beginning. What shall we do first?"

"The first thing to do is to throw away your folding penknife. That kind is of very little use. The steel is so poor it won't hold a cutting edge for any time at all, and the knife has a treacherous habit of closing up on your fingers. I will give you a good Swedish whittling knife like mine, and we will start by putting a good cutting edge on it."

So the boys began the first lesson. The fun they had and the things they made, their many experiences, the patience required, and the great skill developed with tools are described in the following pages. What they accomplished, any other boy may do if he will but apply himself with all his energy.

II

FIRST EXPERIMENTS — THE KNIFE AND ITS POSSIBILITIES

THE older boy, after a search through his treasure chest, selected a knife with a blade about two and a half inches long.

Incidentally, the smaller boy caught a glimpse of the inside of that chest and it made his eyes bulge — but that is another story.

"This knife," explained Ralph, "is one I used for over a year in school and it's the most perfectly shaped tool for whittling that I have ever seen. Of course knives come in hundreds of shapes for different purposes, and later on, when you have become skilled in using this one, we will try some others, but our first motto must be 'one thing at

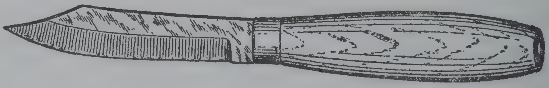


Fig. 1. The whittling knife

a time.' A knife with either blade or handle too long or too short is awkward, but this one seems to fit my hand, and undoubtedly will fit yours. Try it."

Harry took it and went through the motions of whittling an imaginary stick.

"Now," said Ralph, "we will go out to the wood pile and see what we can find. White pine makes the best wood to start on, because it is usually straight grained, soft, and free from sap; but it is getting scarce and expensive, so we must be economical, as it is a very easy matter to waste lots of lumber."

After some searching, they found part of a pine board, about a foot long and an inch thick. Ralph chopped out a piece with a hatchet and deftly split it to about an inch and a half wide. His skill was a revelation to Harry, who saw that even a hatchet could be used with precision.

"Now," said Ralph, "I want you to cut this piece of rough pine to a smooth, straight piece, just an inch square."

"Oh, that's easy," replied Harry eagerly. "Just watch me."

"Take care," said Ralph. "I said an inch square; anything less than an inch will be wrong. Just imagine that this is a problem in arithmetic and you are trying to find the answer. If you succeed in making it just an inch square the answer

will be correct; anything larger or smaller than the exact size will be wrong. In the first place, hold your knife so that it makes a slant or oblique angle with the wood, like this" (Fig. 2), he said,

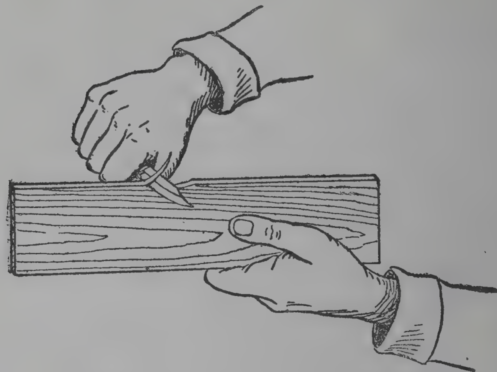


Fig. 2. Correct way to hold the knife

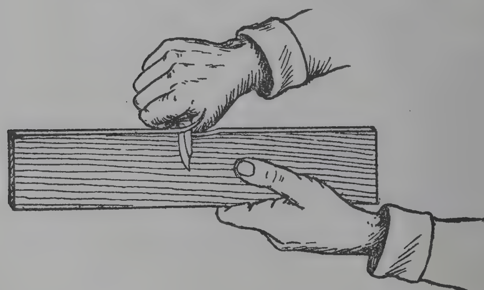


Fig. 3. Incorrect method of holding knife

taking the wood in his left hand and the knife in his right. "That gives what we call a paring action, and is much easier (Fig. 3) than the stiff way you were holding it, at right angles with the stick.

Photograph by Helen W. Cook

The Boy and His Jack Knife

"Now remember that the trouble with beginners is that they usually take off too much material. Make light, easy cuts and try to get one side of the wood perfectly straight first."

This was a harder job than Harry had expected, but after much testing and sighting (Fig. 4) Ralph

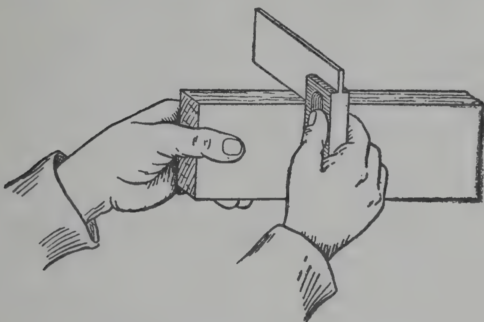


Fig. 4. Testing with the try square

said it would do for the first attempt. "Now," he said, "you may consider this first side the foundation of your house. Make a pencil mark on it near one of the edges, what the woodworker would call his witness mark. It means that this side or face is finished and the edge nearest the pencil mark is to be trued up next."

This proved even a harder job than the first, because after whittling and testing until he had the second side straight and true, Ralph tested it with a square and found that the second edge was not

at right angles with the first, or working face. It was finally straightened, however, to stand the try square test fairly well.

An inch was next marked off at each end on face number one, and a sharp pencil line drawn from end to end. Harry then whittled this third side down to the line, and tested again with the try square. It seemed easier to do now, and the thickness was obtained in the same way. It looked as if they never would get that piece of pine exactly square, and even when Ralph said it would do, they measured it with a rule and found it an eighth of an inch too small each way.

Harry was disgusted. "The answer is wrong after all," he exclaimed, "but I'll learn to do that if it takes me a month."

"That's the right sporting spirit," said Ralph. "Keep at it till you get it. It's the hardest thing you will ever have to do with a knife, and it's unfortunate that you have to tackle it the first thing; but it's like learning to play the piano, you must learn the notes and scales and how to use your fingers before you can play a real piece. Every time you try this, you are gaining skill and the control of your hands. After a while you will be able to do it easily and think nothing of it."

Several days later Harry brought in a piece that he had been working on and Ralph tested it carefully with rule and try square. He gave Harry a pat on the back. "Good for you, boy; you are coming along splendidly," he said. "How many of these have you tried?"

"Twenty," said Harry meekly.

"Well, now, I'll show you how the Indians used to record their exploits. We'll put a notch on this stick for every one you've tried to make, and you can keep it as a souvenir of your first attempts at whittling." So with great care they measured

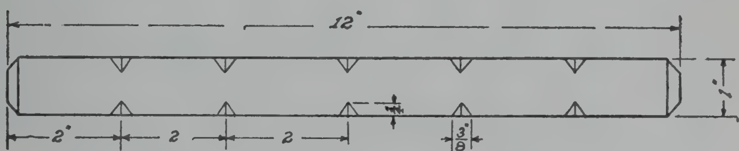


Fig. 5. The notched trophy stick

off six two-inch spaces on each edge, carefully drew notches with a pencil and rule, and as carefully cut each notch to the line. (Fig. 5.)

Harry was delighted with the result.

They then hunted up a small screw eye, found the exact centre of the end of the stick by drawing two diagonals, fastened the screw eye in the centre and tied to it a piece of red, white and blue ribbon.

A quarter-inch bevel was made around each end as a finishing touch.

This piece of white pine, with its twenty notches, hangs to-day in Harry's room, and every once in awhile he counts the notches to make sure they are all there, and recalls the trial that each one represents.

Harry was so much pleased with his notched trophy stick that he wanted to begin something else at once, and he was immediately started on a key rack.

"Too many homes," said Ralph, sagely, "have no definite place to keep keys. Those that have no tags are always a nuisance. Every key or bunch of keys should have a tag attached and should be hung on a certain hook where it can be found without searching. Now we'll make a sketch of a key rack before doing anything else, to find out just how large a piece of stick we shall need."

The drawing they produced is shown in Fig. 6 and called for a piece of wood seven inches long, an inch wide, and half an inch thick. As the key rack was to be a permanent household article, they decided on gum wood as more suitable than pine, it being easy to work and having a satisfactory appearance.

The different stages in the process of cutting out are shown in Fig. 6. At *a* is shown the stock squared up with the knife to the extreme outside

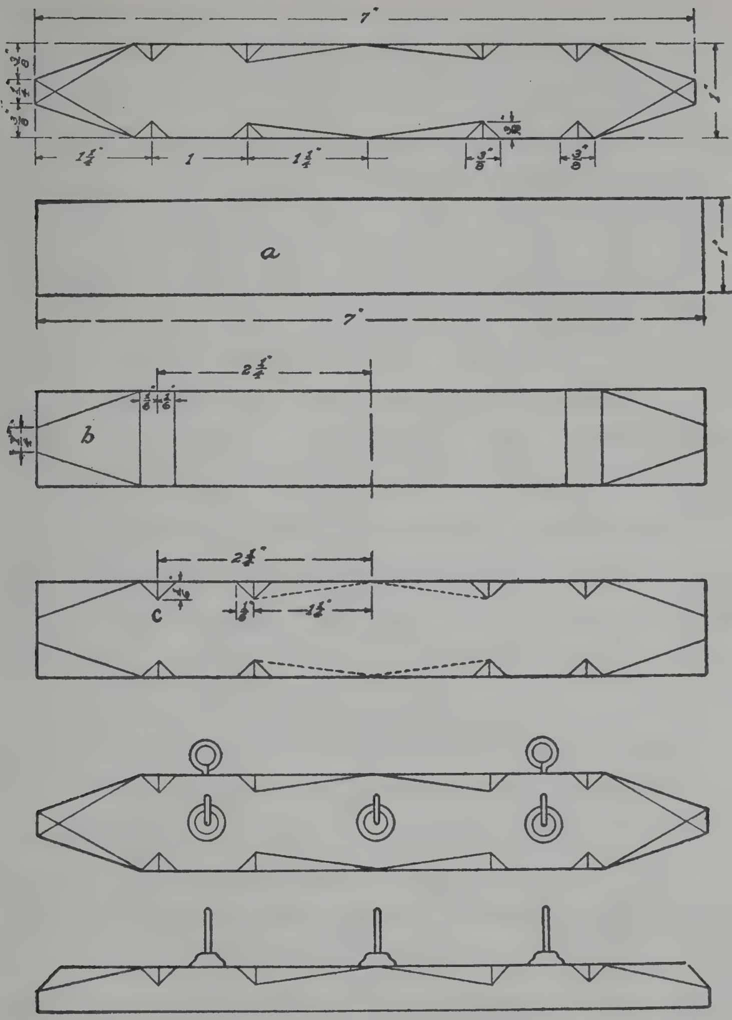


Fig. 6. The various steps in making a key rack

dimensions. The ends were then whittled down to the form shown at *b* and the blank piece was ready for notching. The notches were carefully drawn with a sharp hard pencil and cut as shown at *c*. The ends were bevelled by whittling to the lines, and the inner edges of the notches in the centre were whittled back to the middle of each edge. Then the knife work was finished.

Three brass screw hooks were placed in the centre of the large blank spaces, and two small screw eyes fastened into the upper edge for hanging the key rack on the wall.

Each stage of the work had been worked out so carefully that the boys hardly realized what a satisfactory result they were getting. When it was finally hung in the boys' room, of course some keys must be put on it, and as they had no tags, the making of some followed as a matter of course. A search through their small stock of woods disclosed a few little pieces of holly, the remains of fret saw work, about an eighth of an inch thick. This proved to be ideal material, and half a dozen key tags were made of the size and shape shown in Fig. 7. The holes were made with a brad awl, the tags fastened to the rings by small pieces of wire, and the names of the

keys printed on the different tags with black drawing ink.

The boys, from this time on, seemed possessed with a mania for making articles to be used about the house. One thing to be manufactured without delay was a winder for their fishing lines.

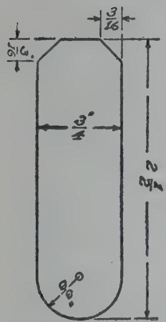


Fig. 7.
The key tag

The form they finally decided on is shown in Fig. 8. Ralph insisted on the design being carefully drawn on a piece of thin wood, a quarter of an inch thick. Harry found whittling to curved lines somewhat harder than notching, but he produced a fairly satisfactory result. Ralph was a very exacting teacher, always having in mind his own training in school. He showed Harry how to cut out the curves at the ends without cutting his thumb (Fig. 9.) and gave him much advice about whittling away from himself, whenever possible.

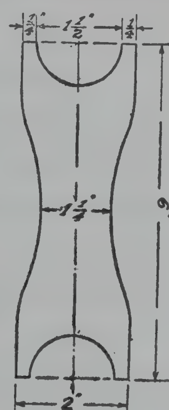


Fig. 8.
Fish line winder

When the knife work was finished, Ralph explained that where curved edges were cut it was allowable to smooth with a piece of fine sand-paper, although as a rule it was to be avoided.

Harry wanted to know why, and Ralph explained that, generally speaking, sand-paper was the hall-mark of a poor workman, one who could not do good work with his tools. Sand-paper leaves a

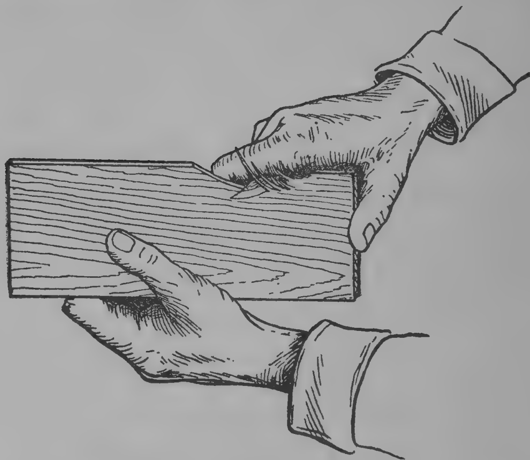


Fig. 9. Cutting concave curves

scratched surface, for the grit becomes embedded in the wood to a certain extent, and it will immediately ruin the cutting edge of a sharp tool in case one has to be used after the sand-papering. "So," he summed up, "keep your sand-paper and knife as far apart as possible."

About this time the ladies of the household thought that a winder for worsted would come in very handy, and the boys evolved a new form, shown in Fig. 10. This was made only an eighth of an inch thick, and proved so easy of construction

that each of the boys made two and "allowed" that "they ought to satisfy the sewing department for some time to come."

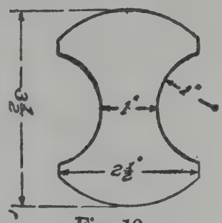


Fig. 10.
The worsted winder

"Do you know," exclaimed Harry one day, "we could make lots of things for Christmas and birthday presents!"

"Why, certainly," said Ralph, "and people appreciate things that you have made yourself much more than things you buy. Anybody can go to the store and buy ready-made presents, but those you make yourself mean more."

"In what way?" said Harry.

"Why, they represent much more of your time and labour, and thought; and, by the way, if we are going to make many Christmas presents, we must start right away, because we only have a few weeks and you know how little time we have outside of school hours after getting our lessons."

The result of this talk was that the little building in the yard which they called their "shop" became a perfect beehive of industry for several weeks. With what money they had saved they purchased a supply of lumber and a few tools the use of which

Ralph said he would explain later. He suggested that Harry begin by making some calendar backs, as suitable New Year's presents, because they were easy; and the more complicated articles could be made after Harry had developed a little more skill with the knife.

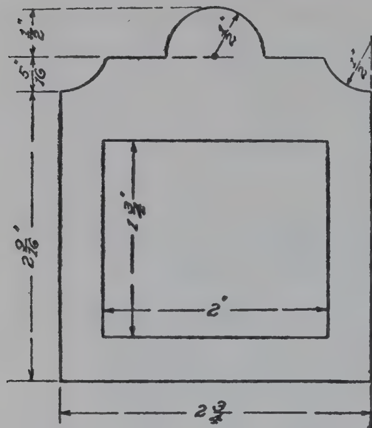


Fig. 11. First calendar back

The drawing he made is shown in Fig. 11. This called for a small calendar about two inches long, an inch and three quarters high, and a space this size was drawn on the centre of the calendar back, while the calendar was glued to the wood.

After two or three of these had been made, Harry decided that they were too small to suit him, and a new design somewhat larger was worked out on paper. It was a little more difficult to follow, because the outline had two reversed curves, but the boys

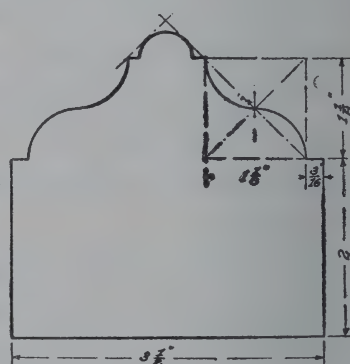


Fig. 12. Second calendar back

were too busy and interested to be daunted by a trifle like that. (Fig. 12.)

Ralph suggested simple picture frames, and this brought the new problem of cutting out an opening for the picture.

The first design they tried is shown in Fig. 13. Ralph had to show Harry how to make the ellipse with compasses by first constructing two squares or rectangles touching, and with both diagonal lines in each square. By taking for a centre the point where the squares touch, as *a* and *b*, and using the length of a diagonal line as a radius, two arcs were drawn at *x* and *y*. The ellipse was finished by taking *c* as a centre, and the distance *c d* as a radius, to draw arc *z*, and the other end was finished in the same way.

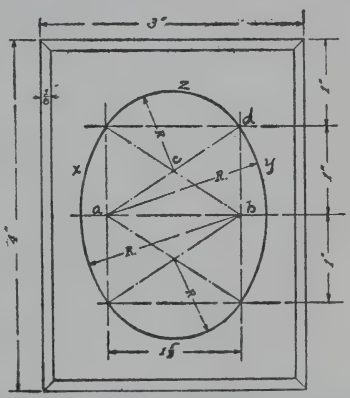


Fig. 13. Picture frame with elliptical opening

Ralph explained that this was not a perfect ellipse, but would answer for a small picture frame. The drawing was easy compared to the question of how to cut out the wood to this curved line.

One of the new tools was brought out, and Harry was introduced to the mysteries of the coping saw. (Fig 14). A thin saw blade was produced and fastened in one end of the frame, the other end being left free. A hole was made inside of the ellipse with

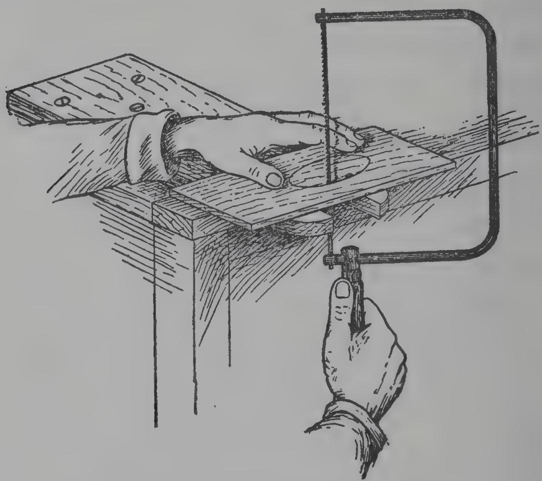


Fig. 14. Using the coping saw

a brad awl, the free end of the blade passed through the opening and fastened in the frame of the saw. Resting the picture frame on the edge of a bench, the ellipse was sawed out roughly about 1/16 of an inch inside of the drawing. This remaining sixteenth of an inch was then whittled to the line with a knife and finished with sand-paper. Harry found some difficulty in getting this elliptical opening

smooth enough to suit him, so they tried designing for half an hour, and produced a new form (Fig. 15).

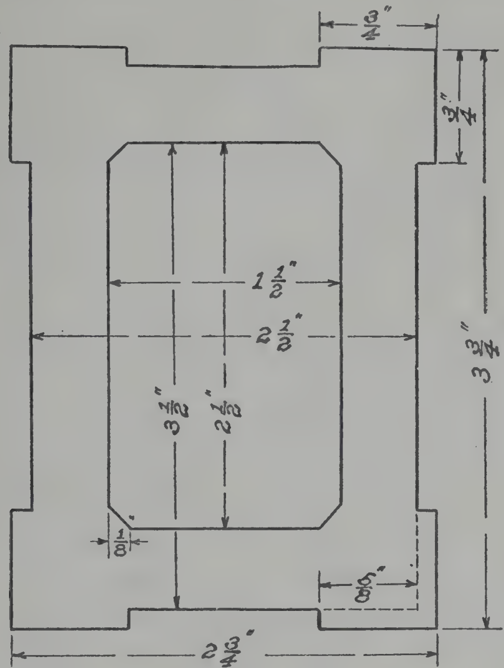


Fig. 15. Picture frame in straight lines

This was easier, as there were no curved lines, and it could be sawed close to the outside as well as the inside lines, to save time in whittling.

III

TOYS

"IN making presents for little children," said Ralph, "we must always remember that the toys will be played with and receive a great deal of rough handling. So to begin with, they must be strong and of simple construction. The youngsters don't care so much for finely finished articles as older people do, and they tire very quickly of things that are so complicated that they get out of order easily. Suppose we first make some neat boxes. They can be filled with candy, and after that is gone they will be used for a long time to keep treasures in."

Fig. 33 shows the drawing of the first box the boys made. The two oblong pieces form the top and bottom. The latter was nailed on with ⅜-inch brads. The two cleats were nailed to the under side of the top to hold it in place, while the sides and ends were fastened with a little glue, and one brad in the centre. This made a very serviceable box, the material being basswood 3/16 of an inch thick.

The sled shown in Fig. 34 came next, made of

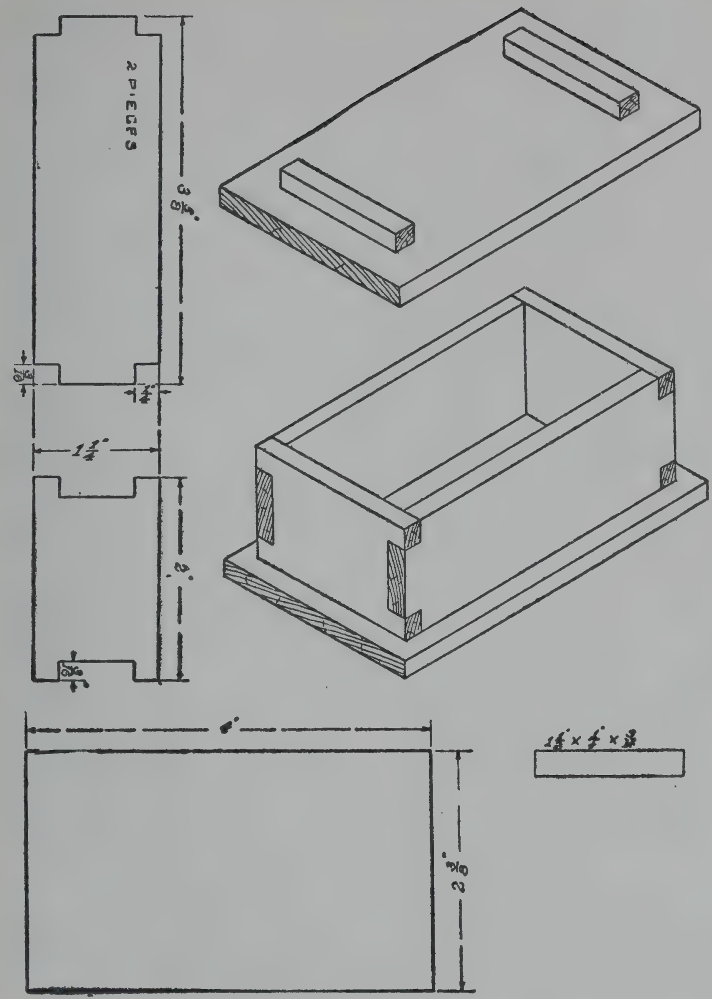


Fig. 33. Toy box

the same material as the box. Ralph was delighted with its strength and graceful lines. Two cleats

were glued into the grooves in the sides, and the top nailed on with ⅜-inch brads.

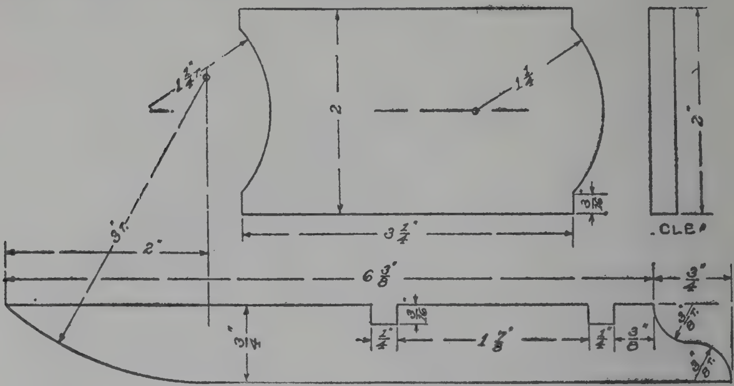


Fig. 34. The toy sled

In each case the drawing was made directly on the wood, which was sawed close to the lines with the coping saw, and finished to the lines with the knife.

The dog house (Fig. 35) brought out some new features of construction. The opening in front was cut out with the saw and finished as usual. Sides and ends were then put together with glue. The two pieces forming the roof were nailed together with ⅜-inch brads, to make a right angle and were then placed in position and nailed to the front and back pieces.

Ralph explained that it was a saving of time and trouble to draw a light pencil line to mark the

location of the brads. If this is not done, the brads are apt to come out in the wrong place and will then have to be withdrawn and placed again. This is a waste of time and it very often spoils the looks of the work, so that the drawing of the pencil lines really saves time in the end, and the lines can be erased.

"We can make any amount of this dolls' furniture," said Ralph. "In fact we could build a doll's house and equip it with chairs, tables, and beds, but what the youngsters really like best is something that works, something that moves, so I move —

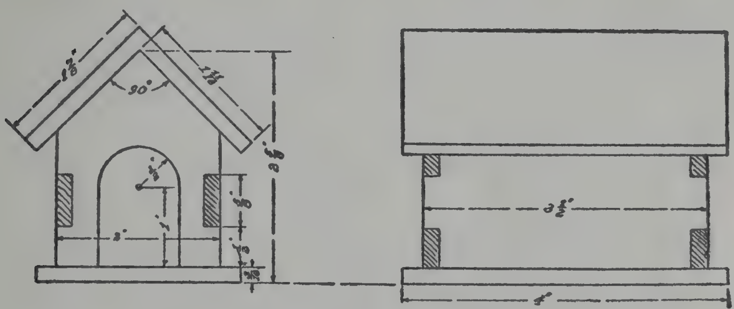


Fig. 35. The dog house

no pun intended — that we design a toy that has some life to it. We can cut it out with the coping saw and there need not be a great deal of knife work to it. Suppose we make an Indian paddling a canoe!" This was more of a problem than they had

bargained for, as it was necessary to look through an encyclopædia to find pictures of canoes, Indians,

Fig. 36. Indian chief

tomahawks, etc. Harry traced the figure of an Indian chief, transferred it to the surface of a piece of ⅛-inch basswood, and on sawing it out found that he had a very good silhouette of an Indian, but it did not move (Fig. 36). The problem was still unsolved, and experiments along that line used up several afternoons.

What was finally worked out is shown in Fig. 37. The arms were made separate from the body, and were fastened to both the paddles and the bodies

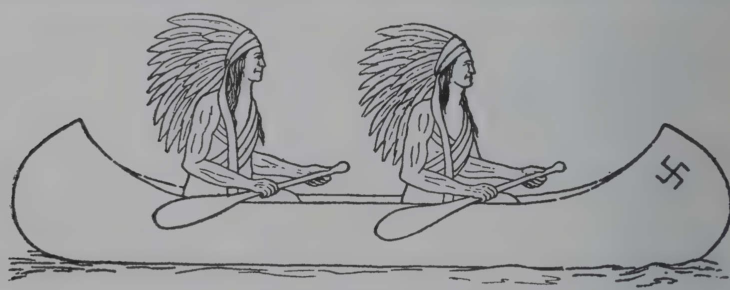


Fig. 37. Indian paddlers

by brads, which acted as pivots. The bodies were then fastened to the canoe in the same way, but a little glue was used as well as brads, as they were to

be immovable. How to make the paddlers move in unison was a hard problem, finally solved by fastening a narrow strip of wood to the lower part of each paddle. It was found that by moving this

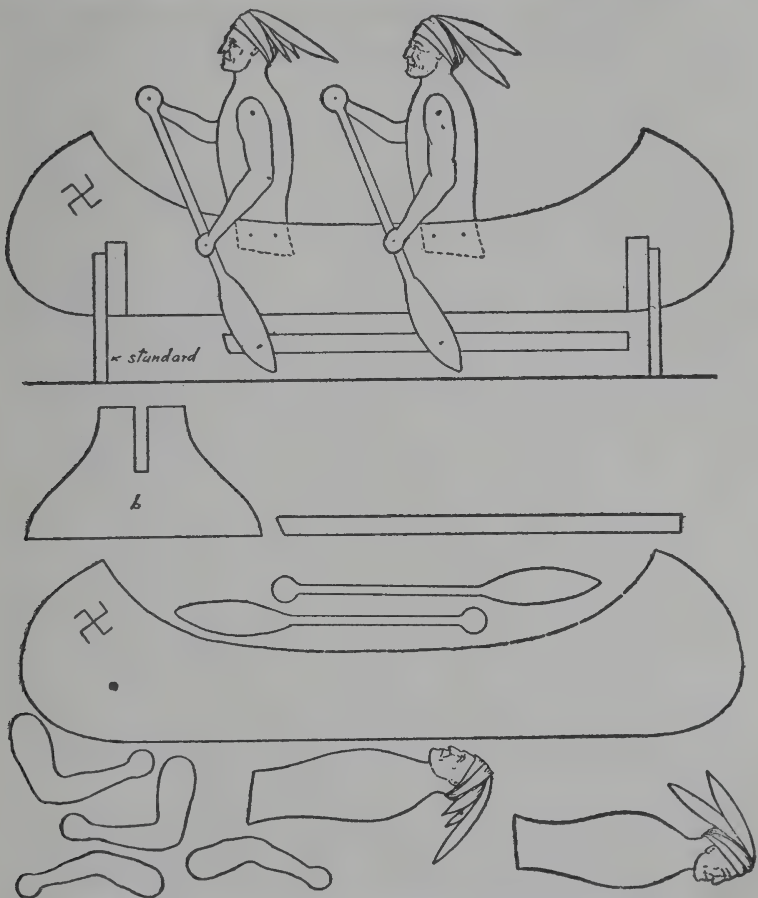


Fig. 38. Indian paddlers. Separate parts cut out and assembled

strip back and forth the two figures moved with the precision of a machine. In each case where a pivot was required it seemed only necessary to drive in a ⅜-inch brad. (Fig. 38.)

The success of this moving toy was so great that the boys went rushing into the house to show it to the family.

Soon they came rushing back again, determined to try their skill on something else. Ralph had to remind Harry that the Indian paddlers were not yet finished, as the toy would not stand up, so the standards shown at *b* were sawed out, smoothed with the knife, and one fastened at each end, as a support, by means of brads and glue.

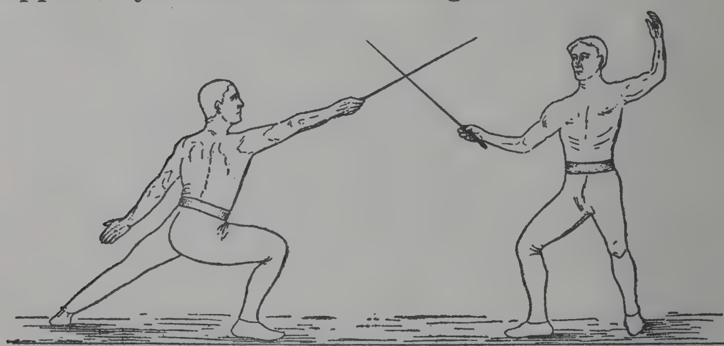


Fig. 39. The fencers

After much boyish arguing, it was decided next to try two swordsmen fencing. This called for some posing, and looking in books to get the correct

position of a man fencing. The drawing shown in Fig. 39 was finally copied from a book on athletic sports.

The different parts of the figures are shown clearly in the illustration. It was found, by experimenting with paper figures, that by making one leg of each figure in two parts, the body, arms, and other leg could be sawed out of one piece.

The work of cutting out and assembling this combination, seemed much easier now that the boys had gotten into the swing of it, and they were so anxious to see it work that they almost spoiled it in their haste. The swords, or foils, were made of two pieces of soft iron wire.

Ralph insisted on filing these out flat near the ends to make them look realistic, and they were fastened by drilling a hole in each hand, passing the wire through and clinching it with a pair of pliers. It was much safer to drill these holes, as a brad awl sometimes splits wood that is very thin. This combination worked to perfection, and while they were trying it Harry caught a glimpse of its shadow on the table. The silhouette in black looked even more realistic than the toy itself, and it gave the boys an idea. (Fig. 40.)

These toys could be used for moving shadow

pictures, and immediately their imagination began to conjure up the programme of a show.

"Our first selection, ladies and gentlemen, will

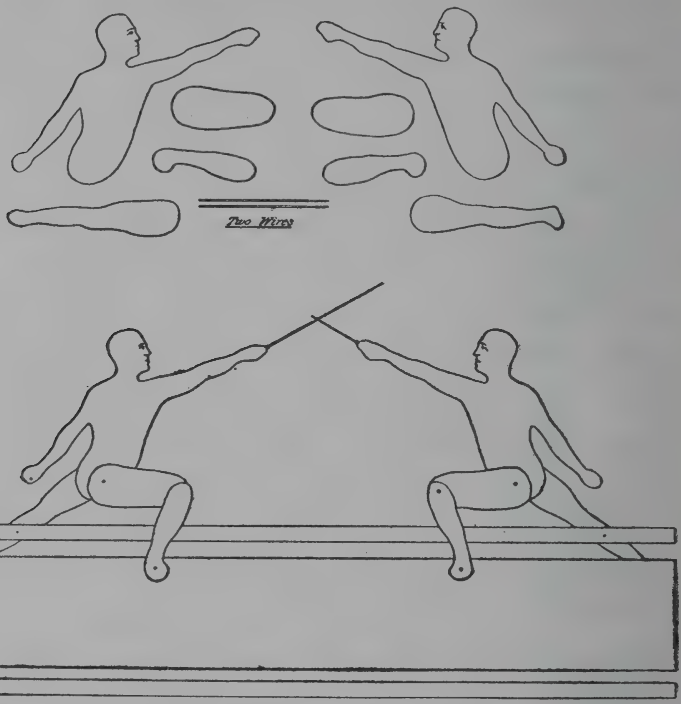


Fig. 40 The fencers. Pieces assembled

be a shadow picture, entitled 'Before the Coming of the White Men'," exclaimed Harry, moving the Indian paddlers.

"And our next will be entitled 'The Duel'," said Ralph.

"Not a very good historical show," said Harry. "We ought to have the 'Landing of the *Mayflower*'."

"Not a bad idea, either," said Ralph. "I think we could rig up a ship in a storm. Let's try that next."

IV

MOVING TOYS

THE problem of making a ship roll proved somewhat of a strain on the engineering corner of Ralph's brain, and after awhile Harry grew restless.

"Can't you give me something to do while you are designing that ocean?" he said.

Ralph, pausing a moment, replied, "Yes, try two men sawing a log."

Harry began to draw, but found that he knew very little about saws, so had to go out and look at one, measured it, and after awhile produced the sketch shown in Fig. 41. Ralph criticised it rather severely, suggesting the addition of a log and saw buck, and advised that the arms of the men and saw be cut out of one piece. The drawing shows the separated pieces, two bodies, four legs, a saw and arms in one piece, two straight pieces for the saw buck, the log, and a little triangular piece to go between log and saw buck. The object of this triangle is to leave a space between the log

and saw buck for the passage of the saw back and forth, as shown in the sectional view.

The two pieces forming the buck were halved together, and the log, triangle, and buck are fastened with glue and two brads.

After all the pieces had been cut out, the men

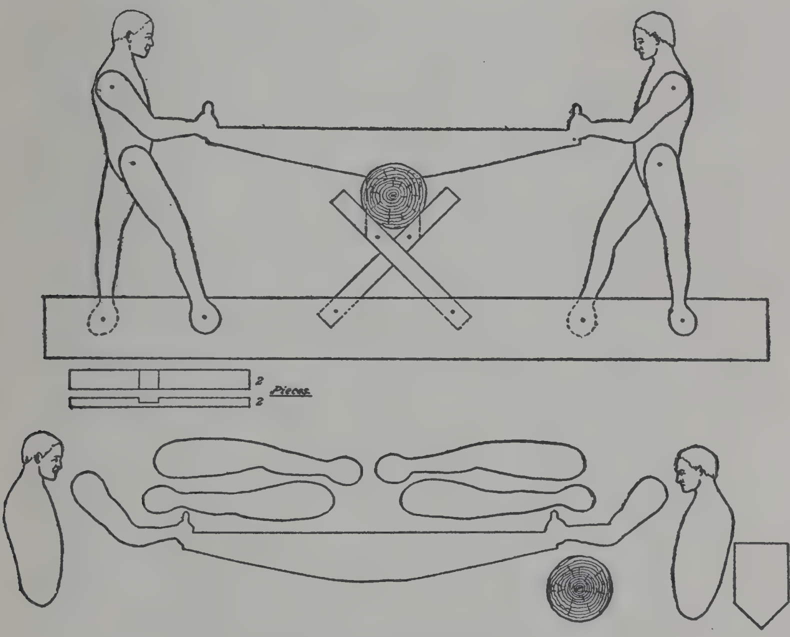


Fig. 41. The sawyers

were first put together by fastening both legs to the body with one 3/8-inch brad.

The feet were next fastened to the straight piece, 10 inches long, representing the ground, by one

brad through each foot, the bodies standing upright, and the feet two inches apart. The arms came next, with one brad through each man's shoulder, and lastly, the saw buck, with the log already fastened rigidly to it, was nailed on the back of the ground piece with the log in front of the saw. To make this toy stand up, two standards were fastened to the ends of the ground piece, the same size as those attached to the fencers in Fig. 40.

It took Harry two hours to make this figure in wood, after he had the drawing finished. In the meantime Ralph had worked out a scheme for giving a boat a rolling motion.

"We'll be mechanical engineers by the time we finish this," he told Harry. "This piece of mechanism calls for a crank, a shaft, two bearings, and a cam, not to mention a ship, an ocean, and a few miscellaneous articles too trivial to mention."

The various parts of "the ship in a heavy sea" are shown in Fig. 42. At *a* is the cam, at *b* the crank and handle, and at *c* the shaft. The boat was sketched free hand and cut out with the coping saw in one piece by sawing exactly on the lines. The ocean was represented by two pieces corresponding to the ground piece in the sawyers, and the wavy outline was not made until every-

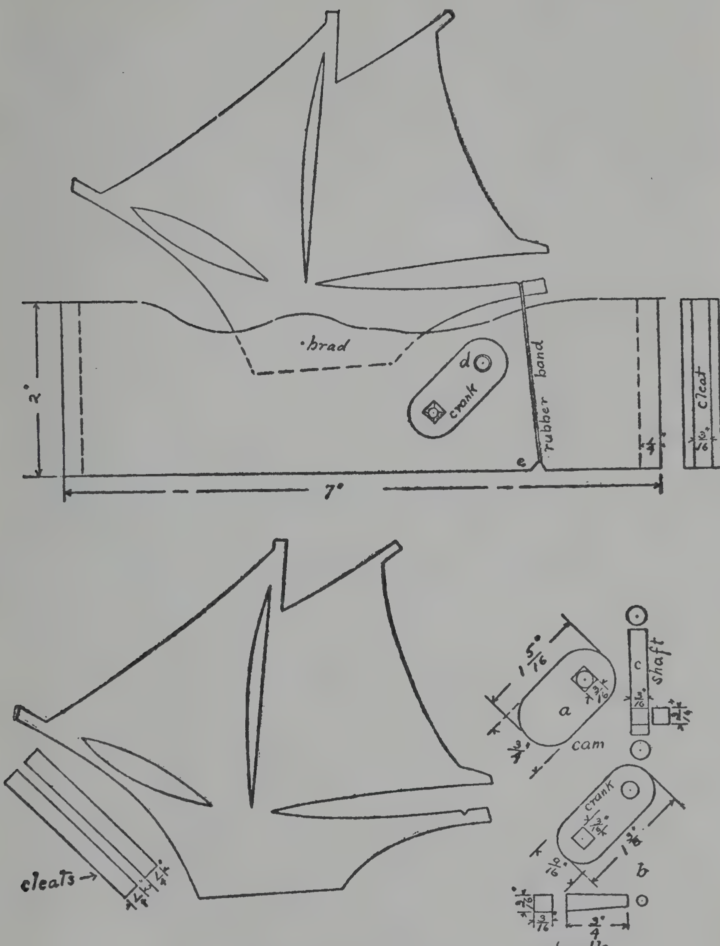


Fig. 42. Boat in storm

thing had been cut out and the combination was ready for assembling.

The most difficult part — the shaft — was made first, and entirely with the knife: A piece of bass-wood was cut exactly a quarter of an inch square, a section was marked in the centre of this 3/16 inch wide, and notches were made on each corner. The two ends were then whittled to an octagonal shape and rounded. The square section in the centre was reduced to 1/8 inch wide and the rounded ends sand-papered smooth.

Next, the cam was cut out, and the square hole made. This was accomplished, after spoiling one, by drilling a quarter of an inch hole in the square and cutting the opening square with the point of the knife.

The object of the square opening was to prevent the cam from slipping when in operation. The cam was then placed over the round part of the shaft and glued to the square section, over which it fitted snugly. Next came the crank. This was made the same shape as the cam, but the 1/4 inch hole drilled in one end was left round, while the other was cut square as in the cam. The shaft fitted into the round hole and was glued in after the assembling. For the handle on the crank, a

piece ¼ inch square was fitted into the square hole, and the rest of it whittled round and sand-papered.

Two cleats, 2 inch x ¼ x 3/16 inch, were cut out with the saw and everything was ready for assembling. The two sides of the ocean were held together and the ¼-inch hole at *d* drilled through both pieces at once.

The two notches at *e* were cut after the assembling was finished. After the holes were drilled, the wavy line was sawed, and the two ends of the shaft inserted in the holes with the cam inside.

The two cleats were inserted in the ends of the ocean and fastened with brads and glue.

Next, the boat was slipped in between the two sides, with the sloping stern just touching the cam, and a ⅜-inch brad was driven through the three thicknesses, sides and boat.

The crank was next slipped over the shaft and glued in position. The crank handle was inserted into the square hole and fastened with glue, and lastly a light rubber band was slipped over the notch on the stern of the boat and the two corresponding notches on the bottom of the ocean. This was to hold the boat against the cam, which gives the motion.

To make this toy more realistic, the boys got out

a box of water colors, painted the body of the boat black, the ocean green, and left the basswood sails their natural color —white.

"There," said Ralph when it was finished, "the youngsters can raise a storm at any time they like

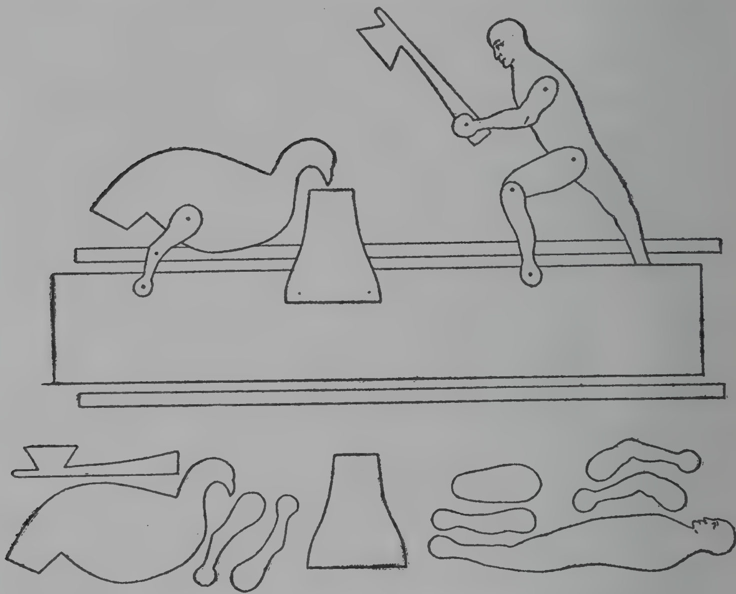


Fig. 43. Turkey and executioner

by simply turning the crank. This toy ought to be very serviceable, as it can't very well get out of order and is almost unbreakable."

The subject of moving toys is almost endless, being limited only by the imagination of the designer. Thanksgiving suggested the turkey and

the axe, and in the toy these boys worked out the turkey evades the axe every time.

The parts are shown in Fig. 43. The legs of the turkey are stuck rigidly to the body by brads and a little glue, and they are fastened to the ground piece by one brad, which acts as a pivot.

The axeman's body and right leg are in one piece, the left leg being in two pieces. The arms adhere rigidly to the body, and the axe to the hands, by means of brads. The operating strip is ¼ inch wide and 9 inches long.

It is fastened between the legs of the turkey, and to the rigid leg of the man, by one brad for pivot in each case.

The stump is nailed to the ground strip from the front.

V

KITES

MAKING and experimenting with aeroplanes calls for much patience and often ends in disappointment — the lot of inventors generally. This is no reason, however, why we should not try our hands at a simpler aerial device of man, which has been the occasion for much good sport. Let us turn to the ancient and gentle art of kite making.

Incidentally, something may be learned about the effect of wind on plane surfaces that will prove helpful in aeroplane work.

The aeroplane kite shown in Fig. 50 is simple and effective. It may be given the appearance of a Blèriot monoplane by modifying some of its features, as shown at *b*, the planes having a slight upward slant. The arrangement of the frames is clearly shown in the drawing. Spruce or white pine may be used, as lightness is an essential.

The method of fastening the sticks is important. It is not wise to halve them, as their strength will be reduced below the safety point, and nails are

likely to split them. Bind them securely with strong linen kite cord or fine soft wire.

Kite *a* is open to criticism on account of the single stick connecting front and back. The second form is better, and the two long sticks may be correspondingly lighter without reducing the ultimate strength of the frame. The method of joining three sticks, as at the forward end, is shown in detail in Fig. 50. Wherever a butt joint occurs, join the two pieces by means of small strips of tin cut to size with a pair of tinsmith snips. Drill holes through tin and sticks, pass fine soft wire through the hole, and twist tightly with a pair of pliers.

The planes or sails may be of light, strong paper, or some light fabric, such as lawn or cheap silk. The fabric should be cut to size, allowing two inches each way for the hem. Pieces of cord are fastened to the hem, and tied to the ends of the sticks through small holes drilled for the purpose, or tied to notches cut with the knife.

The advantage of this method is that the sails, or planes, may be drawn tightly or removed without loss of time. In this way a number of fabrics can be used for experimental purposes. Paper, on the other hand, must be lapped over sticks and wires, and glued.

Propellers may be fastened to front, rear, or both, to create the appearance of a real aeroplane.

The restraining action of the cord holding one of these kites up against the wind brings into action the same force that supports the glider or aeroplane, and the sails, especially fabrics, assume the curve of a boat sail, when close-hauled and sailing into the wind.

The forms that are possible are infinite, and limited only by the imagination of the designer.

It is well to begin with one of the standard types, and leave experimental forms until some experience has been gained.

The Americanized Malay, Eddy, or parakite is shown in Fig. 50. The two sticks are of equal length, bound together with twine or soft wire. Distance *c e* should be from 14 to 18 per cent. of the total length *c d*. The vertical stick remains straight, but cross stick *a b* is bent back like a bow, the distance *e f* being 10 per cent. of the total length of either stick, and maintained by a string from *a* to *b*. The four points *a c b d* are joined by a cord drawn taut, to make sure that the sticks are at right angles.

The material should be cut as shown, the amount lapped being uniform all around. This is important,

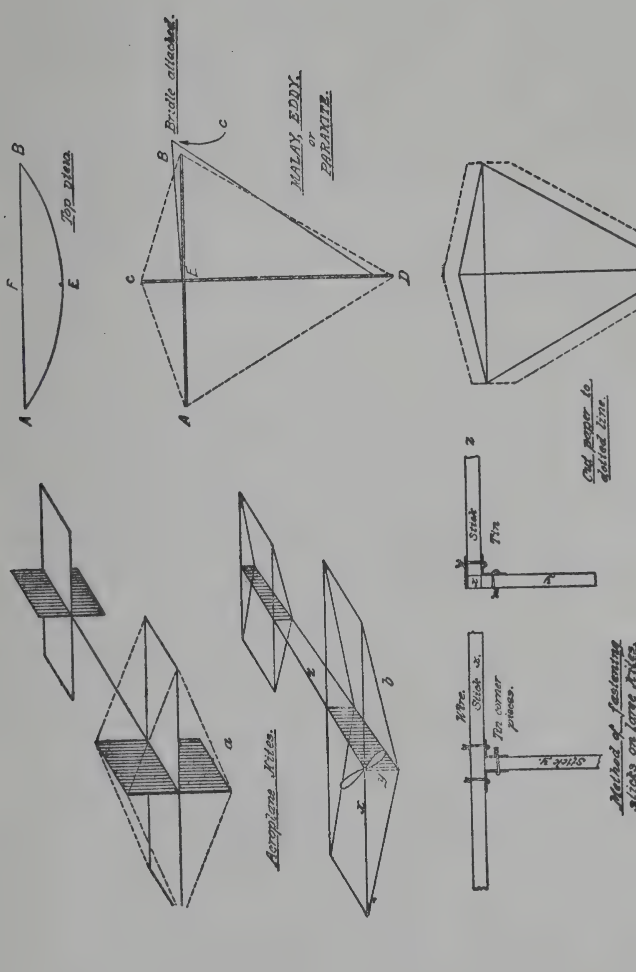

Top piece.
Bridle attached.
MALAY, EDDY or PARAKITE.
Cut paper to dotted line.
Aeroplane Kites.
Wire.
Stick x.
Tin corner pieces.
Stick y.
Stick
Tin
Method of fastening sticks on large kites.

Fig. 50.

as a slight difference in weight between the two sides would result in erratic flying. For Eddy kites up to three feet in height a light-weight wrapping paper will answer very well. Larger sizes require nainsook, lawn, or China silk. Like all the kites described here, this is a tailless one, and the method of fastening the bridle is shown. Make a small hole in the covering, pass a cord through, and tie it to cross the stick at its centre. Fasten the other end about half an inch from lower end of upright, and make a loop at *o* for attaching the line.

The kite line should be the light and strong linen twine made especially for this purpose, and sold by toy and sporting goods dealers. A ball containing 600 yards of cord, strong enough to hold any three-foot kite, will cost about fifty cents.

For larger sizes, it pays to make a reel, to save time drawing in and to avoid bad tangles. A simple form of reel is shown in Fig. 51.

The frame has a generous-sized hole bored as shown at *h*. Cut a small branch in the form shown, *i*, and use this as a stake. Drive it into the ground through *h*, and use it as a pivot to shift the reel as the wind changes. With this arrangement the kite cannot drag the reel, and it is possible to leave

the apparatus with the kite in the air. The writer was driven to using this device after seeing his reel go tearing across the fields until stopped by a four-foot fence. The pull exerted at the reel by a train of three or four kites is sometimes sufficient to give a boy all he can do to hold it. The height to which a kite will go is illustrated by the diagram. *S* is the starting point, and *s t* the direction of the string at the start, when but little cord has been played out. The position of the kite at various times is indicated by letters *a b c d e*, the actual path being shown by dotted line. The solid, curved lines from *s* to these points show the position of the cord as it is played out. This is a mathematical curve resulting from the weight of cord and kite, wind pressure on cord, and lifting power of the plane.

It will be seen that the kite finally moves along horizontally, no matter how much cord is played out. This occurs when the lifting power equals the force of gravity and wind pressure. In other words, the kite can do no more without an increase of wind.

To make it go higher, we must raise point *s* by tandem flying, attaching another kite and cord to the first one, as shown at *x*.

Three or four Eddy kites may be flown in this way, the lines of equal or unequal length joined at a common point to the main line; and, strange as it may seem, if they are well balanced kites they will not interfere with each other. In fact, there seems to be an electrical repulsion among the lines, so that they spread out like a broom.

This is one of the most interesting discoveries in kite flying, though badly upset in actual practice, when one member of the team becomes erratic and proceeds to make a braid of the four cords by diving under and over the others to bring about a general demoralization. For this reason, it is wise to test each kite separately, first, to discover any possible tendency to freakishness.

A weird experience may be enjoyed by leaving the tandem out after dark. Run the main line down by slipping it under your arm, and walk out until you reach the junction of the four lines, where a light-weight lantern can be attached. Let go, and see the lantern apparently drawn up into the air by noiseless, invisible hands.

Flags and other devices may be attached as indicated in the drawing; a light stick at *a b* will keep the flag from blowing up into a heap, and loops

at *a* and *c* are tied in the main line to avoid sliding.

THE BOX KITE

The cellular kite is made in several forms. The rectangular box variety is perhaps the most common,

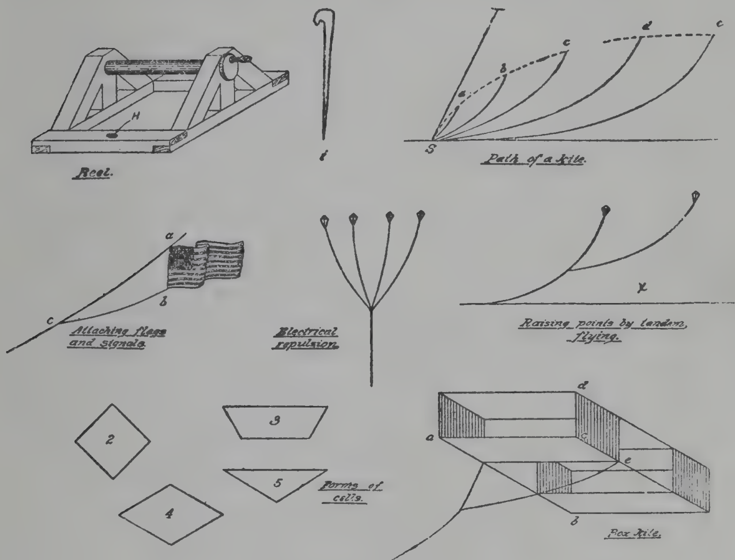


Fig. 51. Kite details

and with the bridle attached is shown in Fig. 51. The standard dimensions are: length *a b* 79 inches, width *a c* 78 inches, depth of cell *c d* 32 inches, and width of cloth covering *c e* 25 inches. A very convenient size is obtained

by dividing approximately by two, making length and width 40 inches each, and depth 16 inches.

Mr. H. H. Clayton, of the Blue Hill Observatory, has patented one form of this kite known as the "Blue Hill Naval Box Kite," so the amateur must confine his use of it to experimenting. Other forms of cells which have been used are shown at 2 3 4 5. These all possess the advantage—that each plane is a lifting surface, whereas in the rectangular form the vertical planes have only a rudder action, tending to hold the kite parallel with the wind.

When launching a box kite, the assistant stands in front of and under it, while with the Malay he stands behind it and lets go at a given word. About a hundred yards of line should be run out before launching, and only a few steps backward by the boy at the string should be necessary. Running is only required when the line out is insufficient.

The tetrahedral form invented by Dr. Graham Bell is unique and interesting. Based on the geometrical figure, it has a remarkable strength of frame, and possesses a surprising lifting power. The principal difficulty in the construction is in

fastening the sticks, as three of them meet at every point. The frame consists of six pieces of equal length. Drill a 1/32-inch hole in each end of all the pieces, about ¼ inch from the end. Place the

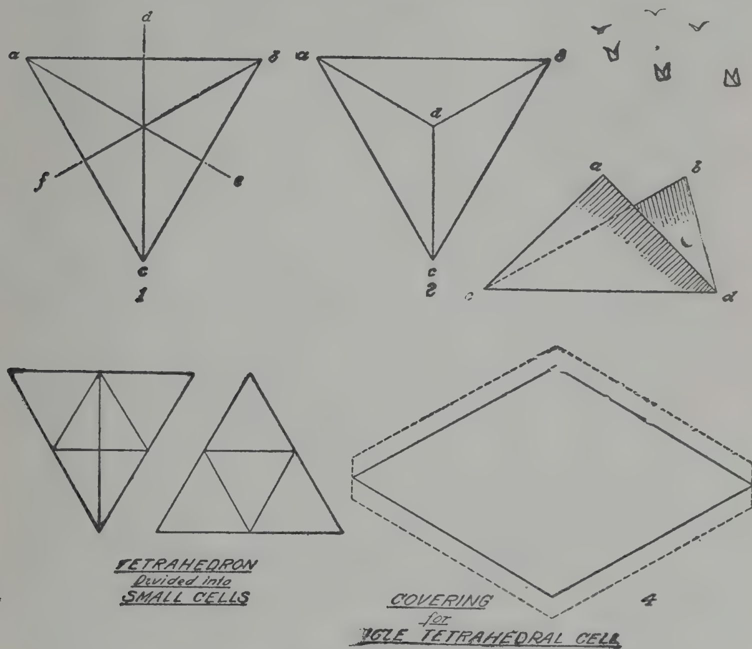


Fig. 52. The tetrahedral kite

pieces on the floor as shown at 1. Pass a piece of soft iron or brass wire through the three holes at *a* and bind lightly. Do the same at angles *b* and *c*. Now raise loose ends *d e f* until they meet over the centre, as at 2. Join with wire and

tighten all the joints with a pair of pliers. (Fig. 52.)

Each face of the frame is an equilateral triangle, and the covering is to be on only two sides, as shown at 3. The shape of the piece to be cut is shown at 4. This forms a single cell, and the large sizes are broken up into many small tetrahedral cells. The line may be tied at *c* or *d*.

The designing of fancy figure kites is a fascinating occupation, but unless certain fixed principles are kept in mind may end in much experimenting and many disappointments. The question of steadiness or stability seems to be summed up in the mathematical expression — "dihedral angle."

A kite having a stiff, flat surface presented to the wind will often cut up queer antics, while the same frame covered with a more flexible covering will fly beautifully. The reason is that the flexible covering will be bowed back by the wind, forming an approximate "dihedral angle."

In the triangular box and tetrahedral kites this bowing back is not so necessary, because the dihedral angle is provided in the construction.

In these kites, when a sudden gust of wind presses harder on one side than on the other, the first side

is pressed back, reducing the resistance, and the other side is brought forward until both sides receive equal pressure, or the kite is in equilibrium, facing the wind; and the shifting of the breeze is constantly provided for. The bowing back of the covering of an Eddy kite takes care of sudden changes in the same way. Double Malay kites or two tetrahedral kites, fastened together, tandem fashion, will be found stable, especially if the rear one be slightly smaller than the forward one. (Fig. 53.)

Geometrical forms like the hexagon, six-pointed

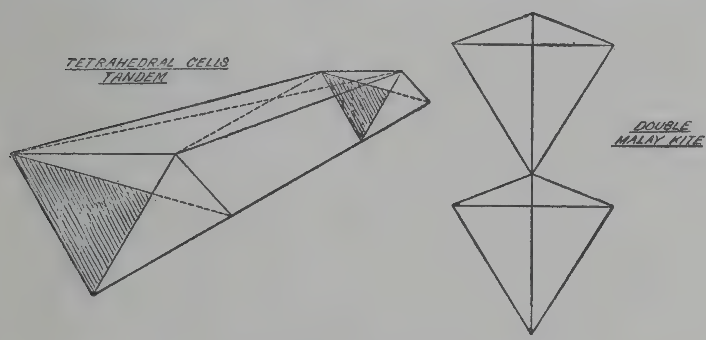


Fig. 53. Double kites

star, and even the circle are used, but these generally require a tail.

A butterfly design may be used, provided the body is designed as a keel and the two wings are tilted backward to provide the required angle.

In some of the Chinese kites, in the form of insects, the wings have split bamboo frames, flexible enough to bend backward and provide the necessary stability. A flexible lower end on the frame also has a good balancing effect.

VI

CHIP CARVING AND KNIFE WORK

"MAKING these toys is a form of dissipation," said Ralph. "It is very fascinating and interesting, but the making of many toys will never make one an expert woodworker. The accuracy and skill required can be developed only by actual constructive work. I suggest that we take up a form of decoration which can be done with the knife.

"There are two ways of making an article in wood pleasing to the eye. One is by varying the outline, as we did in our picture frames, and the other is by some kind of surface ornamentation. There are many ways of decorating surfaces — carving, pyrography, staining, polishing, etc., and very often several of these methods are combined.

"As we have started to learn the possibilities of knife work, I propose to teach you a form of carving which can be done with the knife alone. Very elaborate work is done with the regular carving tools. This requires a great deal of time and skill,

but with the knife alone a wonderful variety of beautiful work can be done even by small boys.

"It is very important to approach it properly, so I am going to give you a few simple exercises and the elaborate designs will come along naturally.

"The work is not new, and evidently grew out of the still older art of notching. Primitive peoples probably saw in it a way to improve the appearance of their various wooden implements. Not only could the edges be notched, but the cutting could be done on flat surfaces as well."

Fig. 54 at *a* shows one of the earliest designs.

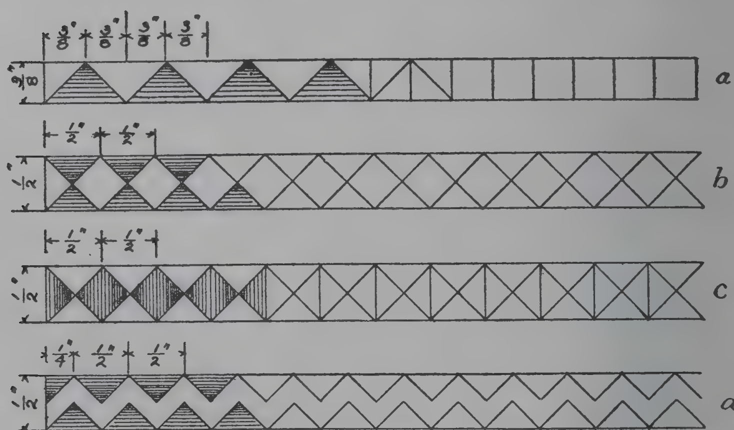


Fig. 54. First cuts in carving

It is simply a border of triangular cuts, and while this may be done with the whittling knife, Fig. 55

shows two knives which are better fitted to do accurate work.

The positions for carving are shown in Fig. 56. Hold the knife in an upright position, with the cut-

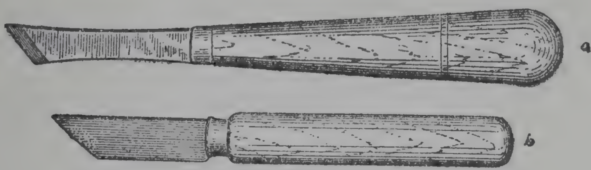


Fig. 55. Two good types of knife for carving

ting edge away from you, and the point on the apex of the triangle. Press the knife down and then away from you along one of the sides of the triangle. Place it in position again, and repeat the motion along the other side of the triangle, always directly on the line. This brings the deep part of the cut at the apex of the triangle, and it remains to take out the triangular chip. This can be done in either of the two ways shown in Fig. 56, by cutting away from you or toward you. It is well to practise both ways, as in complicated designs the direction of the grain makes it necessary to cut sometimes in one direction, sometimes in another.

The rest of this border is a repetition of the same stroke, and the more elaborate designs are simply different arrangements of triangular cuts.

In Fig 54, *b* shows two rows of these same shaped cuts, one row inverted, to produce a diamond-shaped border; *c* shows a border in which the drawing is similar to *b*, but vertical triangles are cut instead

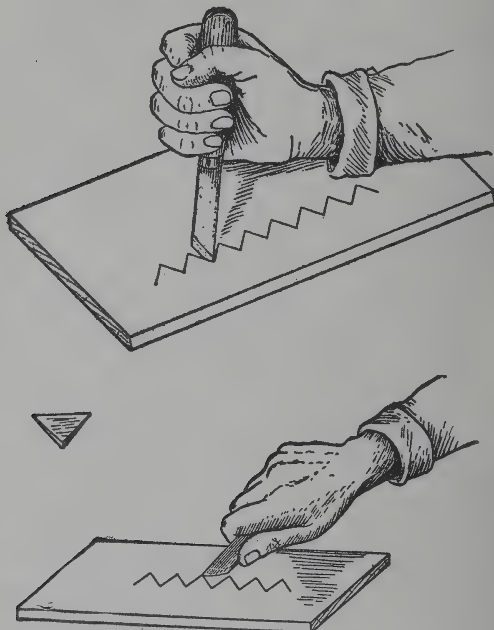


Fig. 56. Positions for holding carving knife

of horizontal ones, as this gives a cut across the grain of the wood instead of parallel to it, and is a trifle harder.

Our boys practised on these simple borders for awhile, using knife *a* and ¼-inch basswood. The work proved fully as fascinating to Harry as

the making of toys, and it was decided that from that time onward the outlines of their woodwork

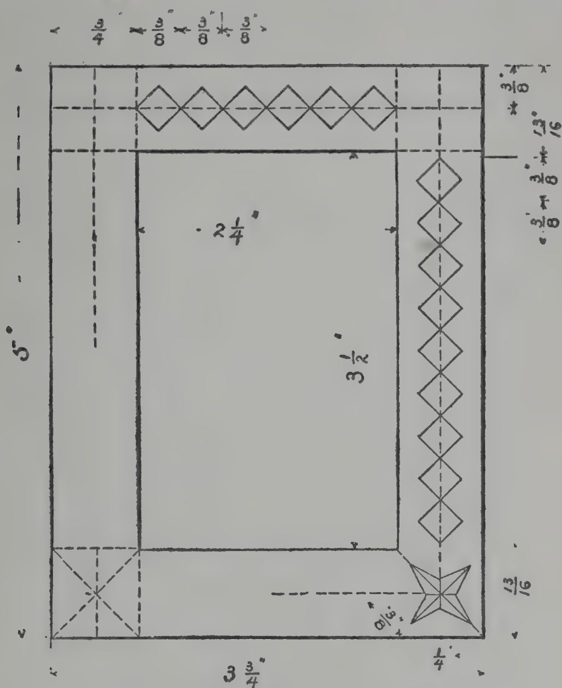


Fig. 57. A simple picture frame with carving

should be simpler, and the decoration should be in the form of chip carving.

While Harry was practising on these simple borders Ralph made the basswood photograph frame shown in Fig. 57, and drew the carving design, as shown, with an H pencil.

To carve this was simply to repeat border *b*.

This was so satisfactory that Ralph decided to try his pupil on finer work, and the design shown in Fig. 58 was tried. In each case Harry found that he was making triangular cuts, and removing triangular chips, just as in the first border, only the

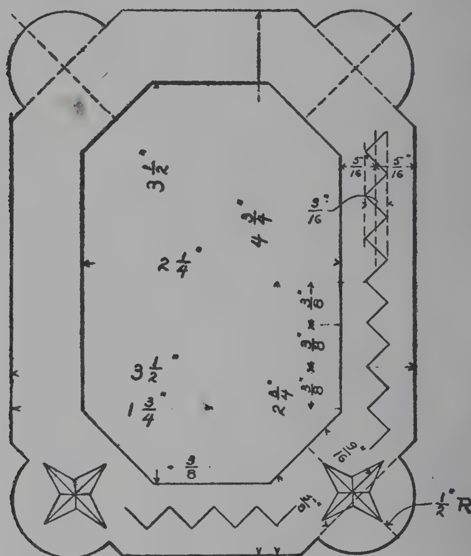
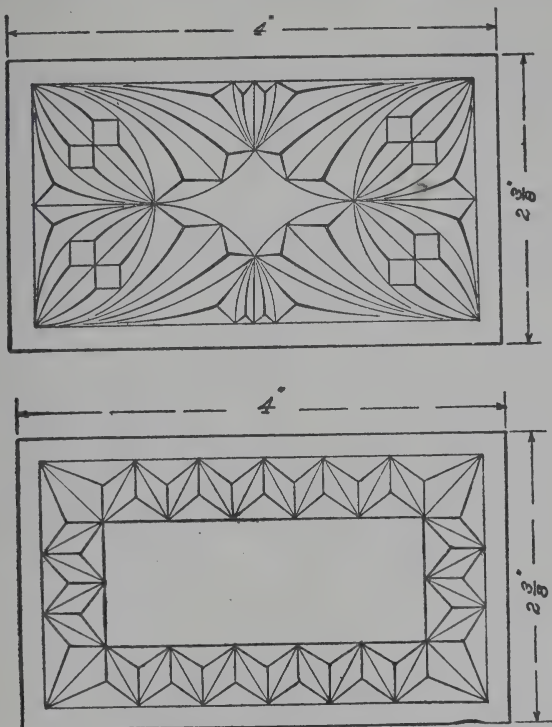


Fig. 58
A more elaborate picture frame

triangles were in different positions. Ralph suggested that they begin to decorate some of the things they had already made, and the little basswood box shown in Fig. 33 was brought out, and the design shown in Fig. 59 drawn and carved upon it.

There followed a number of "backs," which

Ralph explained could be used as thermometer backs, match scratchers, calendars, key racks, and in other ways. In each case, the design was drawn



Figs. 59 and 60. Designs for box covers

carefully on paper, and thence transferred to the surface of the wood with the same care that it had been done on paper. The designing required considerable thought.

Where a border continued around four sides, the

corner became the most difficult and interesting part of the design, and was worked out first. (Fig. 61.)

Very soon the boys found that it was necessary

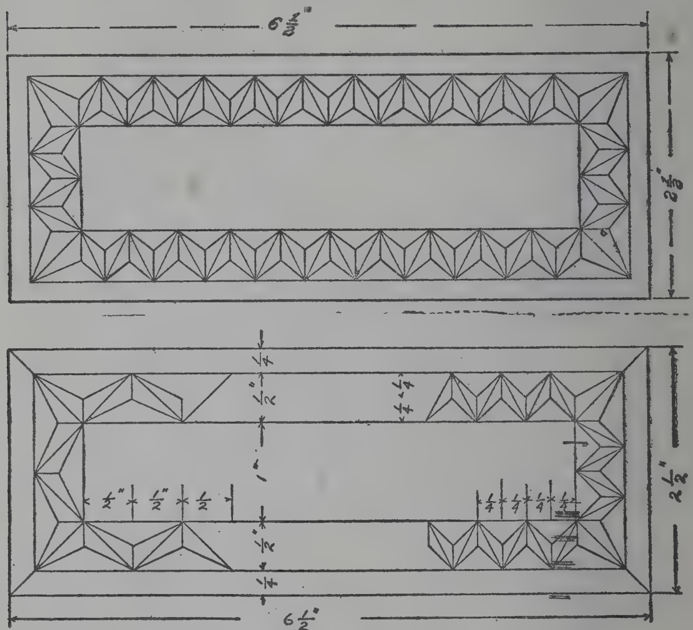


Fig. 61. Straight line designs for thermometer backs

to draw only half the design on paper, and in many cases a corner or quarter sufficed.

The next step was to initiate Harry into the mysteries of curved cutting, a departure from triangular cutting.

He was informed that the cuts were still three-sided, one or two of the sides being but slightly curved.

Fig. 62, used as an enrichment of a "back" in ⅜-inch gum wood, was Harry's first effort in curved

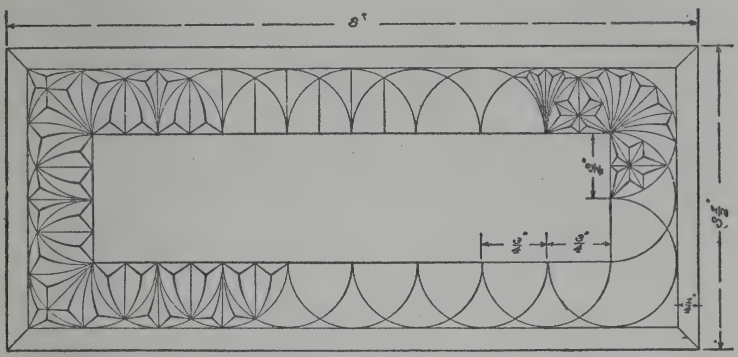


Fig. 62. Curved cuts.

chip carving. The edges of the blank piece were bevelled with a plane and Ralph showed his pupil how to do this by holding the blank against a bench

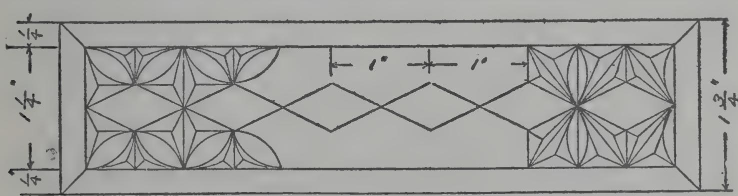


Fig. 63. Key rack

hook. The long sides were bevelled first, the ends last, to avoid breaking off the corners.

The key rack (Fig. 63) gave an opportunity to use centre pieces inside a border, diamonds of the flat surface being left uncarved for the placing of the screw hooks.

A pencil box for school followed, the various pieces being shown in Fig. 64. The two sides and ends were made in one strip 1¼ inches wide, and afterward cut to length. To secure this strip of uniform width, the shooting board shown in Fig.

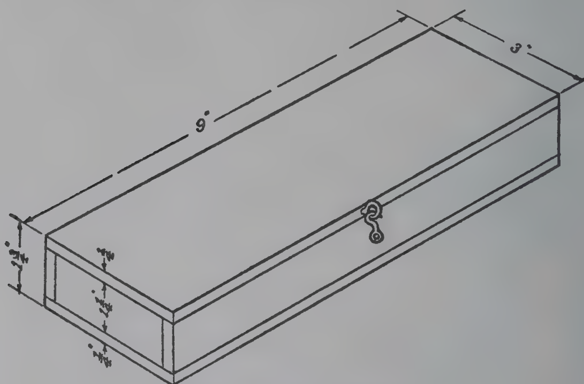


Fig. 64. The pencil box

65 was used, the plane being laid on its side, giving the ¼-inch piece of gum wood a perfectly square edge.

Ralph was having his own troubles as a teacher about this time, for he wanted to reserve Harry's education in the use of bench tools until later on, when he should have exhausted the possibilities of the knife; but this method of using the plane was necessary if Harry was to produce blank forms fit for decoration.

The six pieces being squared up, a ¼-inch margin

Photograph by Arthur G. Eldredge

The Correct Way to Hold the Chisel

was left on all sides of the pieces to be carved — the top, front, and two ends.

This ¼-inch space was for the brads.

The assembling was not done until the carving had been finished, and it consisted of fastening the long sides to the ends with ⅝-inch brads, with a little glue on the end grain of the end pieces. The bottom was put on with brads, and the top hinged

Fig. 65. Use of shooting board

to the back by two small nickel-plated hinges. A little hook and eye from the hardware store were put at the front to hold the cover on, and two small cleats were glued to the under side of the cover to keep it from warping.

The time spent on this pencil box was several hours, but the result was a box the like of which could not be bought.

Pencil boxes became the rage with our boys,

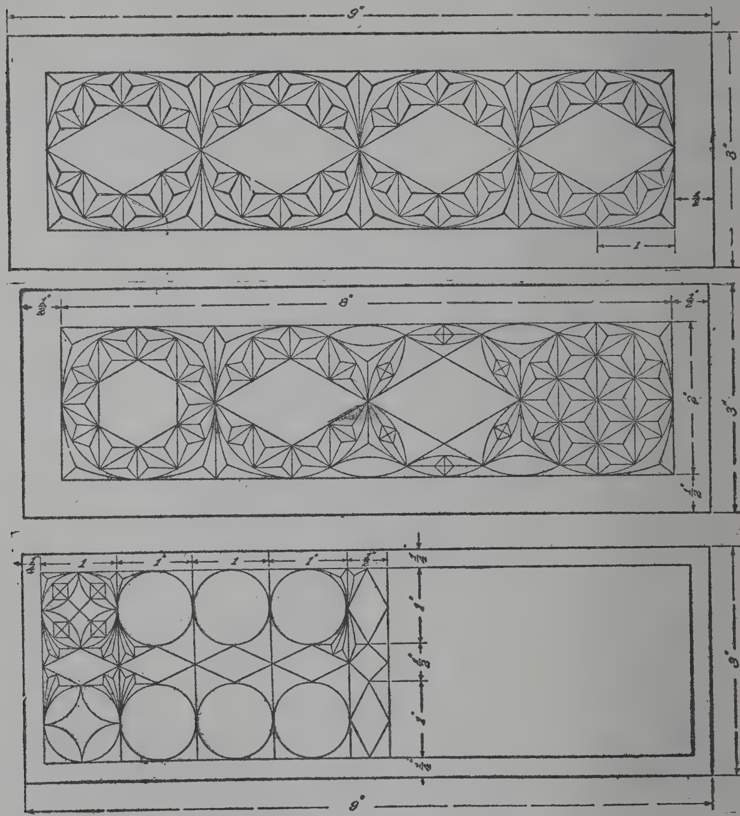


Fig. 66. Carving designs for pencil box

and although they made several of the same size, in each case the design was different. (Fig. 66.)

VII

THE SHOP

THE man who is most successful is the one who is best prepared for his work. In beginning to learn how to use wood-working tools, the average boy is very often hampered by the lack of facilities. The place he is to use for his shop should at least have good light. Many of the lines he uses are knife lines, which are harder to see than pencil lines, so that light at least is an essential.

The tools should be as good as he can obtain. This does not mean that it is necessary to have elaborate sets of chisels, gouges, etc., but the cutting tools should be of well tempered steel. It is far better to have a few very good tools than an elaborate equipment of poor ones, such as the boy's ready-made tool chest often contains.

A good workman is one who can do a large variety of good work with a few well-selected tools.

One reason for our having given so much space to knife work was to illustrate this very fact. Very

often the carved pieces described in previous chapters are salable at good figures, and from the money thus obtained a supply of bench or carpenters' tools can be bought.

Next to a well lighted place in which to work, a fairly good bench is essential. This can be made by the boy himself, if he cannot secure one already built, but as the construction of a bench presupposes some previous practice with tools, we will assume that our readers receive their first tool practice on a bench already built, just as Harry did.

Several forms of benches on the market are shown in Fig. 87.

The bench to be of any use must have a vise of some description, as very often both hands are required to guide the tool, and the wood must be held rigid.

The old-fashioned screw vise is cheap, and a cheap vise may be made at a cost of half a dollar, by purchasing the screw and nut and making the jaw and guides by hand, but this again calls for the use of a bench. So taken all in all it will pay the young woodworker to save his money and buy a good vise even if the bench is home-made.

This is just where our boys had their first argument; Harry wanted to begin by building a work bench.

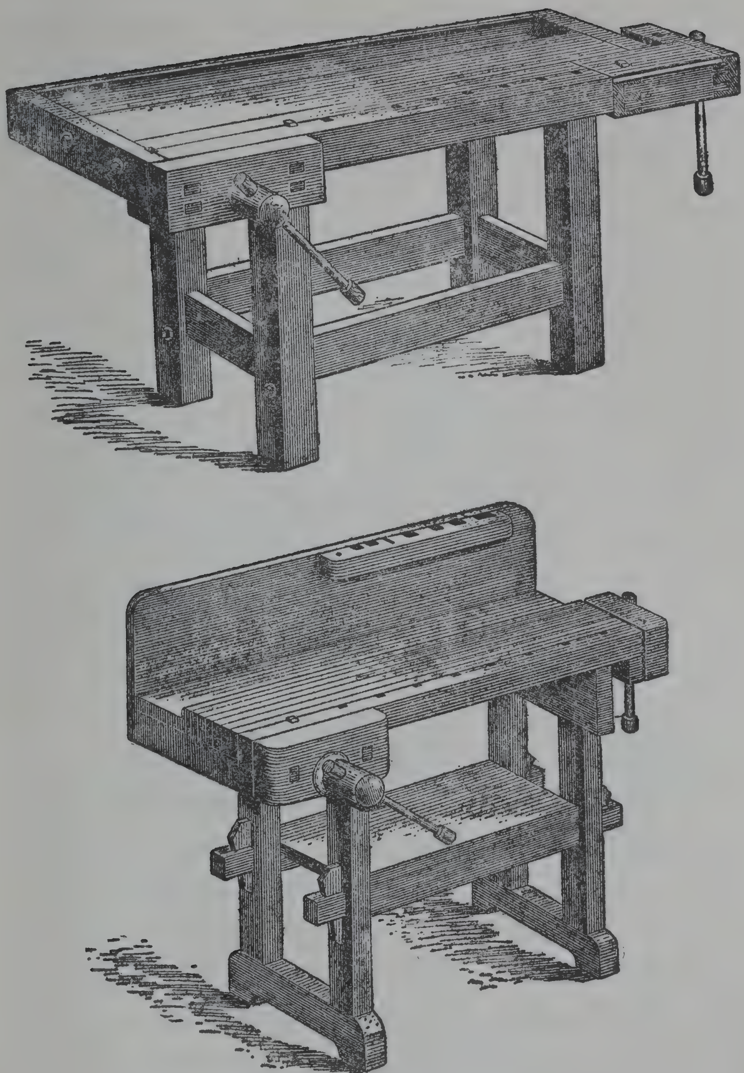


Fig. 87. Types of work bench

"That is where you are wrong," said Ralph. "Perhaps you remember that you wanted to begin knife work by making a paper cutter, and as a matter of fact it was very nearly the last thing I gave you to do. It required all your skill and previous practice to accomplish it. It will be just the same with the bench and vise. You will be able to construct them, but only after considerable experience with tools. You might as well insist on making all your tools before starting to use them or you might insist on going into the woods, cutting down trees and ripping out your own planks for stock. Just wait a minute."

He went into the house and came out with a pamphlet on lumbering, which he opened at the picture shown in Fig 88. It represents the old style of sawing out planks by hand before the coming of the saw-mill.

The man in the pit is called a pit man, the one on the log, the sawyer. This method of cutting lumber was in vogue up to about fifty years ago.

"This," said Ralph, "is what your line of reasoning would lead us back to, so if I am to be your instructor you must leave these things to my judgment, and my advice is to start work with a good bench having on it a good vise."

To let you into a family secret, the boys' work in carving had been admired by several friends and they had worked up quite a trade in making and selling their carvings. From the money they

Fig. 88. The old way of getting out lumber

had saved they purchased the bench shown in Fig. 89. It was very well built, having a heavy top of 3-inch maple and a modern quick action vise. The seven drawers underneath were not

really necessary, but the boys found them very handy for storing tools, nails, screws, unfinished work, etc.

The space under a bench is very apt to become a catch-all and a nuisance, so as time went on they concluded that the extra cost of this bench was

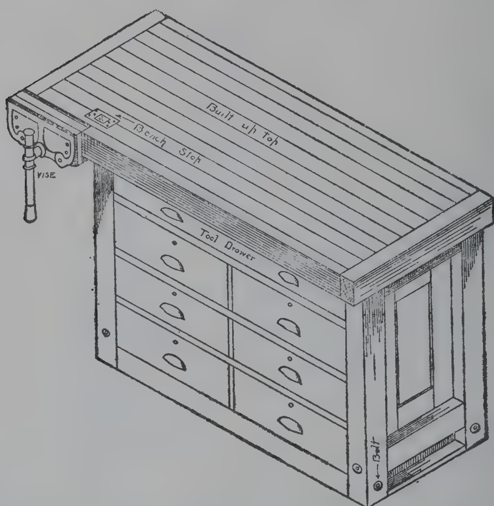


Fig. 89. Bench with quick action vise

justified, although at the time the price seemed very high. Some of the cheaper benches they looked at are shown in Fig. 87.

The quick action vise was a great time saver, as it could be pulled wide open or pushed back without turning the handle, as in the old screw vises.

A dozen of these quick action vises are on the

market, and may be had at hardware stores for from four dollars upward.

This flat topped bench had no tool rack, and could consequently be worked on from any side. At first, the owners kept most of their tools in the large drawer at the top, but later on they made a good sized tool cabinet, which was fastened to the wall and will be described later.

The iron bench stop also proved a valuable feature, as it could be fastened at any desired height by a set screw, or dropped down out of the way below the level of the bench top. When planing thin wood, one end of the board is braced against the bench stop. Ralph found that starting with a new bench had another advantage. It helped his pupil to take good care of the bench. Harry was very careful not to saw or cut it as he might have done with an old bench, and to foster this spirit of carefulness, Ralph gave him for his first problem the making of a bench hook. (Fig. 90.) The tools used in its construction were:

24-inch rip saw	Brace and ¼-inch bit
20-inch cross cut saw	Countersink bit
Marking gauge	1½-inch flat head screws
Try square 6 inches	Piece of maple, planed to ⅞-inch thick, 12 inches long, 10 inches wide
15-inch jack-plane	

The maple board was first laid out as shown at *a*, a pencil line being drawn 2 inches from one

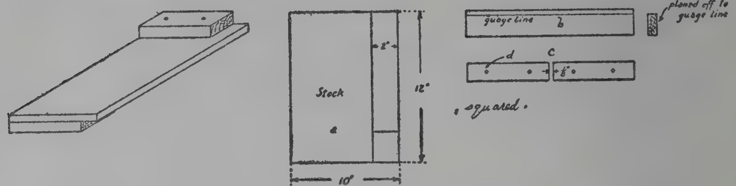


Fig. 90. The bench hook

edge. The piece was placed in the vise horizontally, and both long edges planed straight and true and tested with the try square.

The block was then placed upright in the vise, and the ends planed square with the block plane. This required much explaining and practise, as the block plane has a bad habit of breaking off the farther corner.

Ralph showed Harry how to use this tool safely by planing only part way across the end and then finishing from the other side. Both ends were tested with the try square.

The piece was now sawed in two by using a rip saw on the pencil line, the wood being held in the vise in an upright position.

This made two pieces of stock 12 inches long, one 2 inches wide, the other 8 inches nearly, as the saw cut had removed some of the wood.

The 2-inch piece was laid out as shown at *b*. The marking gauge was set at 1¾ inches and from the joint edge — that already planed — a line was gauged on each flat face, and the sawed edge planed to these lines as at *b*.

It was then laid out as shown at *c*, two knife lines being squared around the four sides ⅛ inch apart. The piece was then sawed apart carefully between these two knife lines, and the ends block planed and tested.

Two ¼-inch holes were bored, as shown at *d*, in each piece, and countersunk with the countersink bit. This makes a place for the screw heads,

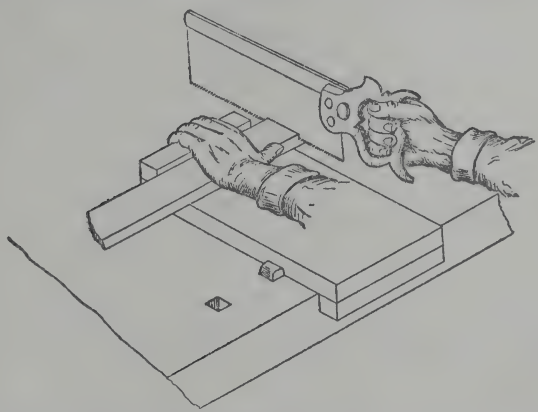


Fig. 91. Method of using the bench hook and back saw

so they will be below the surface where they cannot be in the way of tools or scratch the bench.

The wide piece was next planed on its sawed edge, and the blocks screwed on. That the bench hook might always be handy and have a definite place of its own, a half-inch hole was bored as shown in the illustration, and it was hung on a nail, set in the end of the bench.

The bench hook is designed to protect the bench from saw marks and the cuts of chisels, gouges, etc. The method of using it with the saw is shown in Fig. 91. Wherever possible, it should be made of hard wood.

VIII

THE EQUIPMENT FOR A SHOP

NOTHING is so necessary to the saving of time and energy as an orderly shop. Our boys had bought a quantity of white pine to begin operations and it was lying in a pile on the floor where it was always in the way.

To cut a piece of stock from one of these 12-foot boards it was necessary to use two kitchen chairs for trestles, so it was decided to construct two saw horses, and as soon as they found time to build a lumber rack against the wall where their little supply could be stored out of the way.

"We will carry out our regular practice by first making a drawing," said Ralph. "We know from experience that it saves time."

Fig. 92 shows the proportions of the trestle at *a*, and the mechanical drawing with all dimensions at *b*.

The body of the trestle was built up of four pieces, two long and two short ones. The open space in the centre, Ralph explained, would make a con-

venient tool rack where hammers, chisels, etc., could be placed while they were working, especially at outdoor work, instead of being dropped on the ground. The body then called for two pieces 3 feet long by 4 inches wide, and two pieces 10 inches long by 4 wide.

These were sawed from a rough plank with the rip saw by using the chairs as trestles. A pencil line was laid out 3¼ inches from one edge, and the saw cut made directly on the line, 8 feet long.

The cross cut saw was used to cut the strip off and this strip was then sawed with the same saw into four pieces of equal length for the legs. Another strip 4¼ inches wide, 7 feet 8 inches long, was ripped out and taken off with the cross cut saw, for the body, and divided into two pieces 3 feet 10 inches long, for convenience in planing.

Harry now had his first real experience in planing. All the pieces were of 1-inch rough lumber, with sawed edges, and had to be planed down to ⅞ inch in thickness.

To plane six pieces of stock straight and true, with squared edges and of definite size, was no easy task.

"How do you like manual labour?" asked Ralph, mischievously.

"I like it all right," replied the perspiring boy,

"but we won't need any gymnasium work for exercise while we are doing this."

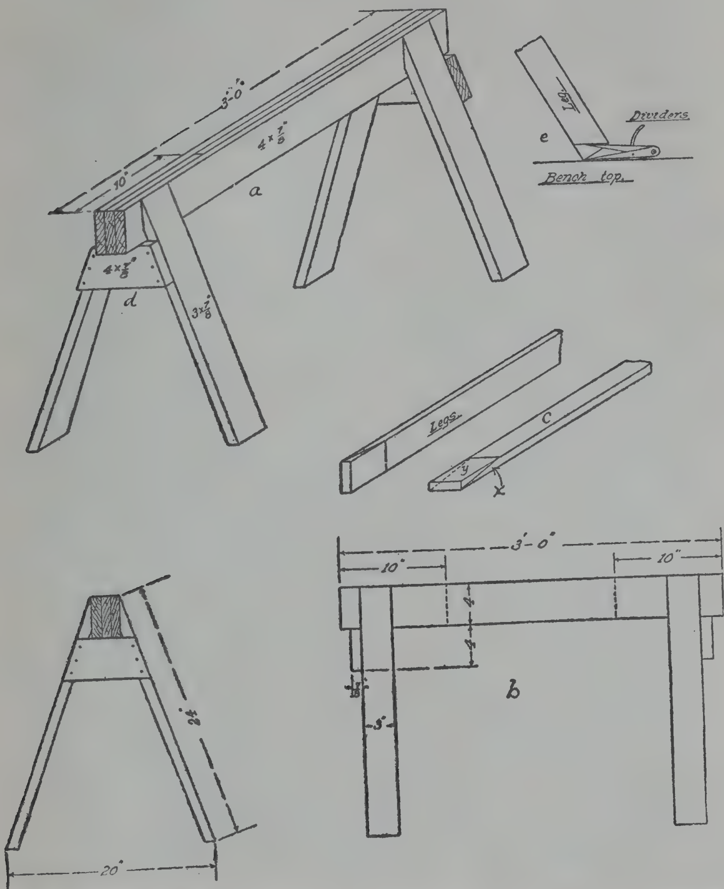


Fig. 92, The trestle or saw horse. By permission of *Carpentry and Building*

"Wouldn't you like to make a bench in hard wood right away?" asked Ralph.

"No, I guess you were right after all."

Ralph showed him the proper way to stand, and how to hold the jack-plane so as to get the best results. He promised to show him how to sharpen and adjust the plane as soon as the lumber was stored away on the lumber rack.

Harry's business was to dress down one of the flat faces of each piece till it was smooth, straight and true both with the grain and across it. He tested it by his eye and the edge of his plane and when he thought it was about right, passed it over to Ralph for criticism.

Ralph was a very exacting instructor, but made allowance for the boy's inexperience. He was making the second trestle at the same time and it was exasperating to Harry to see the ease with which he turned out his work.

"Never mind," said Ralph, "you can do as good carving now as I, and in a few weeks you will be able to do just as good joinery or carpentry. The first day is always the hardest. You are all impatience and want to get through right away. After a while you will learn by experience that you can only do one thing at a time, and will not rush so."

Finally, one face on each of the six pieces was pronounced finished, and the next step was to

Photograph by Helen W. Cooke

Using the Jack Plane

"joint" or "dress down" one edge straight, smooth and square with the working face — the first planed surface. This seemed easier after the experience of making the bench hook, and Harry knew how to test for squareness with the try square.

Working on the two long pieces for the body, both edges of each were squared up, a 10-inch piece was marked off on one end of each with pencil and try square, and sawed off with cross cut saw.

It was decided to leave the inner faces rough, as they would be inside the trestle, and out of sight. These four pieces forming the body were now nailed together with 2½-inch wire nails, as shown in *a*.

The four pieces for the legs were dressed on all four sides, and it only remained to cut the angle at top and bottom.

This brought into use a new tool, the bevel. The angle *x* was found by laying the bevel on the mechanical drawing, and fixing it at the angle by tightening the set screw provided for the purpose. The line was carried across the face by means of the try square, and the bevel used on the farther edge. When this laying out was finished, the piece looked like *c*, the triangular piece *y* being removed by sawing directly on the pencil lines.

After the four legs were laid out in this manner and cut, they were nailed to the body with 3-inch wire nails.

The saw horse was now complete with the exception of the two braces, and the final truing up.

The braces were made by holding a piece of stock 4 inches x $7/8$ inch in position and marking the slope with a pencil, sawing to pencil lines and nailing in position *d*.

The final process of truing up was an interesting one to Harry, and he used it many times afterward in finishing pieces of furniture, such as tables, tabourettes, etc.

The horse was placed on the bench, and a pair of dividers set as shown at *e*.

A line was scribed on each leg wherever the compasses point touched it, holding the latter upright and going around all four sides of each leg. By sawing to the lines made in this way, the trestle was found to stand on the floor perfectly true. This is a method much used in truing up articles that rest on three or more legs, and it overcomes any inaccuracies that may have arisen in the process of assembling; but it is very important that the surface on which this truing up is done shall itself be perfectly true. The bench used in this case was

new and had not yet warped at all, but an oid bench might not have been suitable. This can be ascertained by testing the surface in several directions with a long straight edge.

The facts of warping and shrinkage in wood must always be taken into consideration.

The saw horse is an important part of every shop equipment, and the boys now relegated the clumsy chairs to the kitchen, where they belonged, and were prepared to saw out stock from their longest boards.

IX

TOOLS: SAWS

THE boys now took up the systematic study of tools, as Ralph suggested that they had spent time enough on toys and boxes.

A cutting tool must be constructed with reference to the material it is to cut. In the machine shop, we find the angle of the cutting edge large — often 80 degrees — while a razor has a cutting edge of about 5 degrees. All cutting tools are wedges, whether saws, chisels, planes, axes, or knives, and the angle depends on the hardness of the material in which it is to work. The action of the tool may be a chisel action, a knife action, or both. In the rip saw, the teeth are really a series of chisel edges cut in one piece of steel, while in a cross cut saw we have a knife action for cutting the fibres, followed by a chisel action for removing the wood.

The side view of a rip saw is shown at *a* (Fig. 101), the end view at *b*.

The chisel-like edges are bent outward to right and left alternately. This is called the "set" of the

teeth and its purpose is to make the cut wider than the body of the saw, to prevent friction. As the saw teeth pass through the wood, the fibres spring back against the saw blade or body, and the friction makes the work almost impossible without "set" to the teeth.

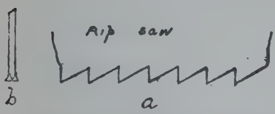


Fig. 101. Teeth of rip saw

All woodworking saws must be set, and special tools called "saw sets" are sold for the purpose of bending out the teeth.

The rip or slitting saw should only be used for cutting with the grain. When used across the grain, the action is exactly like that of a narrow chisel, and it will tear the fibres instead of cutting them.

The teeth of a cross cut saw are shown in Fig. 102. At *a* is the side view, and at *b* the end view. The teeth are set and filed to a knife edge. This gives two parallel lines of knife-like teeth which cut the fibres in two parallel lines, while the body of the tooth cuts out the wood in the form of sawdust.

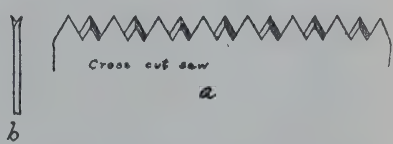


Fig. 102. Teeth of cross cut saw

All woodworking saws belong to one of these two classes, and the cutting angles of the teeth are shown in Fig. 103.

We are very apt to regard the saw not only as a very commonplace article, but as a fixed quantity which has always been the same and always will be. As a matter of fact, the saw has gone through a process of evolution the same as the electric motor, automobile, and aeroplane. New methods of its manufacture are constantly being invented and improvements made in its construction. Some of the steps in the process of making a hand saw are: rolling the steel plate of which the body is made, hardening, tempering, hammering or smithing, grinding, polishing, filing, setting, etching, handling, and blocking.

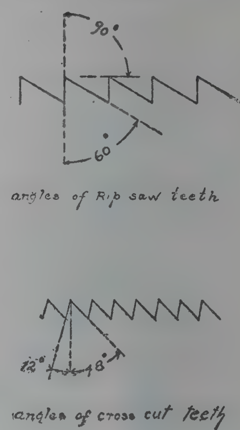


Fig. 103

The handling refers to the placing of the wooden handle and some idea of what it means is illustrated in Fig. 104, showing two methods of attaching the apple wood handle.

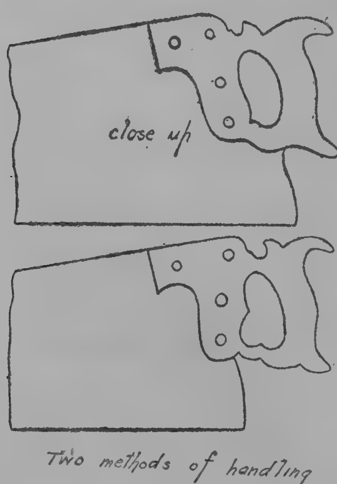


Fig. 104

Some idea of what the

Photograph by Helen W. Cooke

Learning to Use the Cross Cut Saw

grinding means is shown by the tapers, or difference in the thickness of the steel, as shown at Fig. 105, the thickness in one thousandths of an inch being given at the different points. It will be noticed that not only does the blade decrease in width from the handle out to the end of the saw, but the thickness decreases from

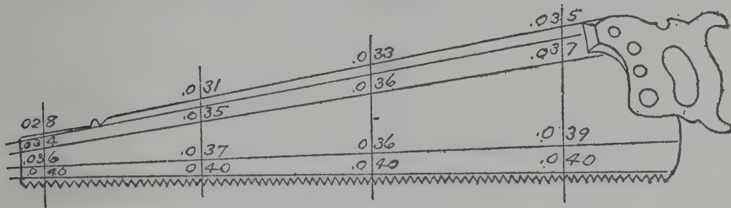


Fig. 105. Thickness of saw blade

the teeth to the top and also from the handle out to the end. This represents ideal saw construction, and it is found only in the good makes.

The back saw, being strengthened by a heavy piece of steel along the top, is made of thinner material, and the tapers are not necessary, for the back piece gives rigidity. It removes less wood, but is limited in its action by the back. It is used chiefly by pattern makers, and for finer bench work, such as cabinet making, but should be part of every boy's outfit.

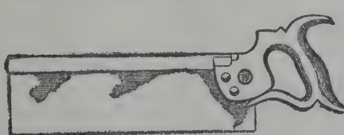


Fig. 106. The back saw

The compass-saw shown at Fig. 107 is used for

general purposes, but is not so necessary as the back saw. It is useful for cutting out small openings, though it is not as valuable for this purpose as the turning saw.

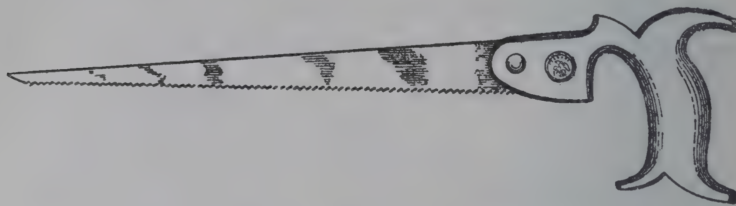


Fig. 107. The compass saw

One end of the turning saw can be released from the frame by removing a pin, passed through a small hole. This is fastened in the frame again and made to follow a curved line like a fret or coping saw.

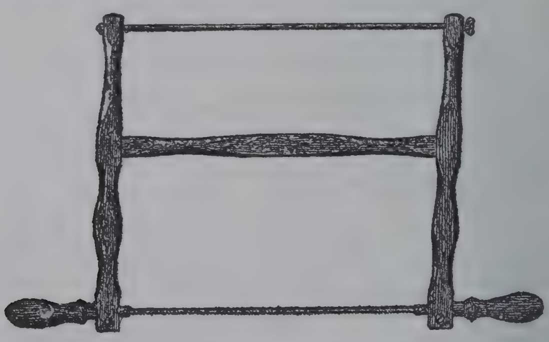


Fig. 108. The turning saw

The number of teeth to the inch varies, and saws are rated as four-point, five-point, etc., according to the number of points or spaces to the inch. For

very hard woods, a saw with small teeth, *i. e.*, with more points than ordinary to the inch, should be used; but a boy who possesses one saw of each kind — a rip, a cross cut, a back saw, and a turning saw— has all that will be required for ordinary wood-work.

Fig. 109. Using the rip saw and trestles

In working with the board on trestles, the saw should be held at an angle of about 45 degrees to the surface. When sawing a board held in the bench vise, this is not so easily done, but the cut should at least be started with the tool in the correct position. (Fig. 109).

The hack saw is used for cutting metal, and while not essential for woodwork, is often valuable for cutting pieces of pipe, rivets, bolts, screws, and nails and should be added to the outfit when the finances will allow. (Fig. 110).

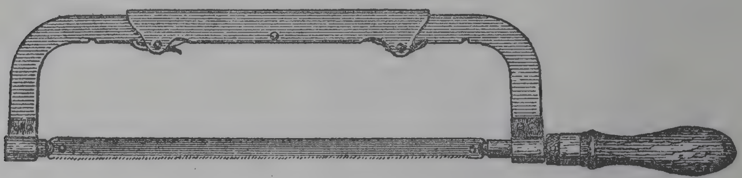


Fig. 110. The hack saw for cutting metal

In fact, there is no such thing as a set of tools. Good tools only should be bought, and the outfit at first should be simple; new ones can be added from time to time, as they are needed. In this way one learns the possibilities of his kit much better than by starting with an elaborate collection.

X

TOOLS: PLANES

A BOY buying his tool outfit is often bewildered by the array in the hardware store. He is further confused by the advice of the salesman, and his own little store of money.

In selecting planes, only three are really necessary for ordinary work, and this number may even be reduced to two.

Wooden planes are still the favourite tools of some woodworkers, but iron planes have largely superseded them. A 15-inch iron jack plane, a 9-inch smoothing plane, and a block plane make a very good combination for a beginning.

Special planes can be added later, as the finances will allow.

The iron plane with its various parts is shown in Fig. 111. These refer to either the jack or the smooth plane.

In the block plane there is no cap iron, the cutter or plane iron being placed with the bevelled side up. There is frequently found on this tool an

adjustment for changing the amount of opening in the mouth for hard or soft woods.

The plane iron and cap are fastened together with a set screw, and the cap is removed when it is being ground or sharpened on an oilstone.

This set screw, which is loosened with a screw-driver, or the edge of the clamp used as a screw-driver, also allows the distance from the cutting edge to the cap to be changed for soft or hard woods. These two irons are fastened into the throat of the plane by the clamp.

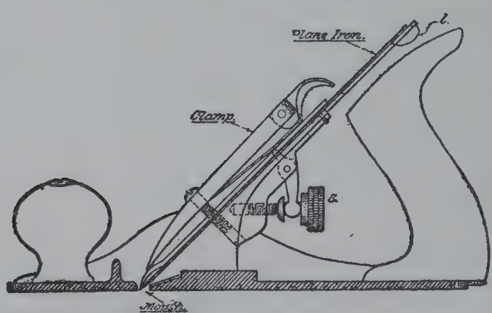
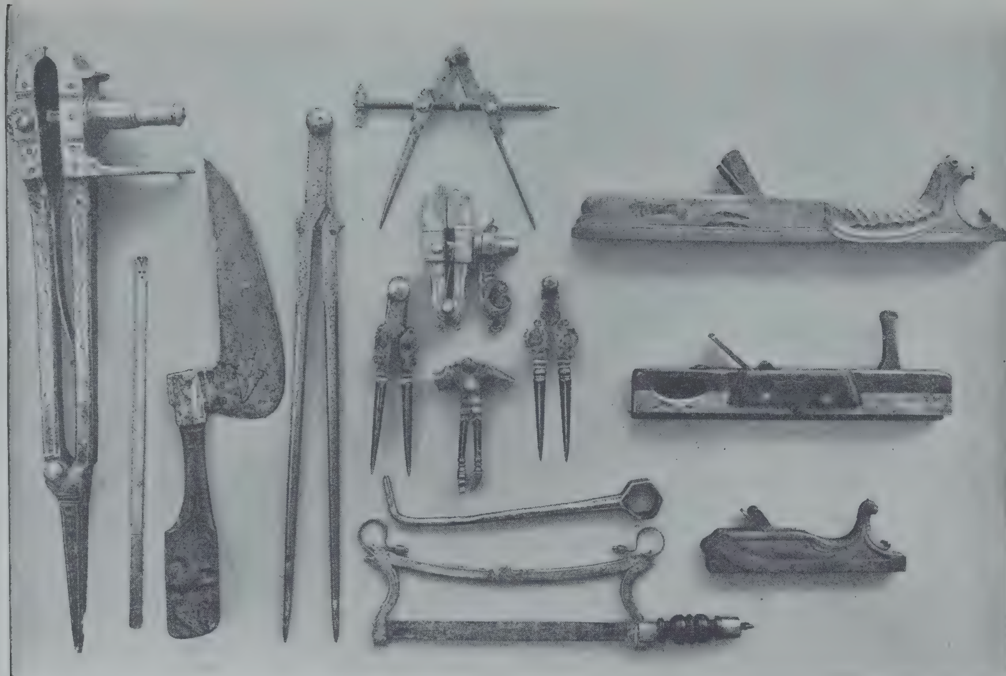


Fig. 111 The smoothing plane

The lever (1) is for straightening the plane iron, and the screw *s* is for adjusting the depth of the cut.

The difference between the jack and smooth planes, aside from the size, is in the shape of the



By the Courtesy of the Metropolitan Museum of Art

TOOLS OF THE SEVENTEENTH CENTURY

Showing how little progress has been made in tool construction. In this collection is a jointer plane, a smooth plane, rabbit plane, straight edge, dividers or compasses, a bench vise, hand vise, wrench, hack-saw and combination tool.

"cutter" or "bit." In the jack plane, the bit is ground with a slightly curved cutting edge. This enables the tool to remove coarse shavings, but leaves a slightly corrugated surface which must be smoothed with the smoothing plane.

The jack plane also tends to straighten the work, owing to its greater length. The greater the length, the more does it straighten. The old-fashioned jointers were made several feet long for this very purpose.

If a boy can afford only one plane, it should be a jack plane, but the cutter should be ground straight to act as a smooth plane.

The block plane can be dispensed with better than any of the others, because the smooth plane can be used on a shooting board for truing up end grain, the original purpose of the block plane.

The latter plane has no cap, as it works on the ends of the wood fibres with a shearing or paring action. This is helped by holding the tool at an angle with the wood, a position not advisable with the other two tools.

The proper position for planing is with the right side to the bench, the plane held flat on the work. Each stroke should, wherever possible, be the full length of the board, unless one

part is higher than the rest of the surface. This may be ascertained by using the edge of the plane as a straight edge. High spots should be marked with a pencil, and then planed off, till the full length strokes can be made, and the edge planed straight and true. In surface planing, if the surface be warped, the amount of wind may be determined by placing two "winding" sticks — two straight pieces of the same size at the two ends — and sighting with the eye along their top edges. To take out wind, it may be necessary to plane diagonally across the grain from corner to corner. This defect is common in lumber not properly piled or seasoned, and is more noticeable in such woods as gum or chestnut.

The sharpening of plane irons is a very important part of one's knowledge of tool work, and of course applies to chisels, gouges, and all cutting tools.

Remember that the cutting edge or bevel is a wedge, the angle of a plane-iron bevel being from 25 to 35 degrees, the smaller angle for soft wood, the larger for hard. This angle is not measured by the woodworker often, but is a matter of experience. If the young mechanic will keep his tools ground to the same angle as he finds them at the time of purchase, he will not go far astray.

This angle should be a clean-cut one, however. Fig. 112 shows some correct and some incorrect ways of grinding. At *a* is shown the right way, *b* is not an angle at all, and *c* is a waste of time and material. At *d* is shown the worst fault of all — a "back bevel." This occurs when the tool is carelessly turned over and ground on both sides, which renders it useless until all the steel in front of the dotted line has been removed; in other words, until the tool is reground.

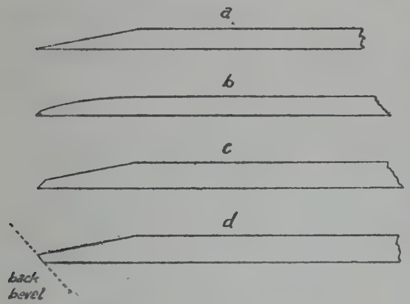


Fig. 112. The cutting angle

This mistake is sometimes made in using the oilstone, by rubbing the tool on both sides instead of on one only. All the grinding and sharpening must be done on the bevelled side. As the plane iron is only a thin chisel, the sharpening of the latter tool is performed as in the case of the plane iron, and the same care should be taken to keep the bevel clean cut.

A good grindstone is a shop necessity, and, one might add, a household necessity, because every household uses knives, and the dull knife is an altogether too common nuisance.

Our boys hung up another sign at this stage, and it read, "Keep your tools sharp." This ought to go without saying, but it is a fact that many people make failures of their work and become disgusted with it because they do not keep their tools in order. The satisfaction of using fine, sharp tools cannot be explained; it must be experienced.

Like other things about the shop, there are many kinds of grindstones on the market. The old-fashioned stone with a wooden frame (Fig. 113) worked by hand or a treadle may be good — it depends on the stone — and the new one with a small stone, iron, or pressed steel frame is handy. The last stone is provided with a bicycle seat, and is worked by both feet, so that the hands are free to hold the tool. This stone has ball bearings, is noiseless, and occupies less space than the other.

A stone that is soft and gritty, rather than one that is hard like a piece of granite, should be selected.

In holding the tool against the stone, some common sense is necessary. The harder one presses, the quicker the grinding, but if there is not plenty of water on the stone, the tool may be "burned." When a black place appears, you have destroyed the temper, showing that there has been too much pressure, or too little water, or both.

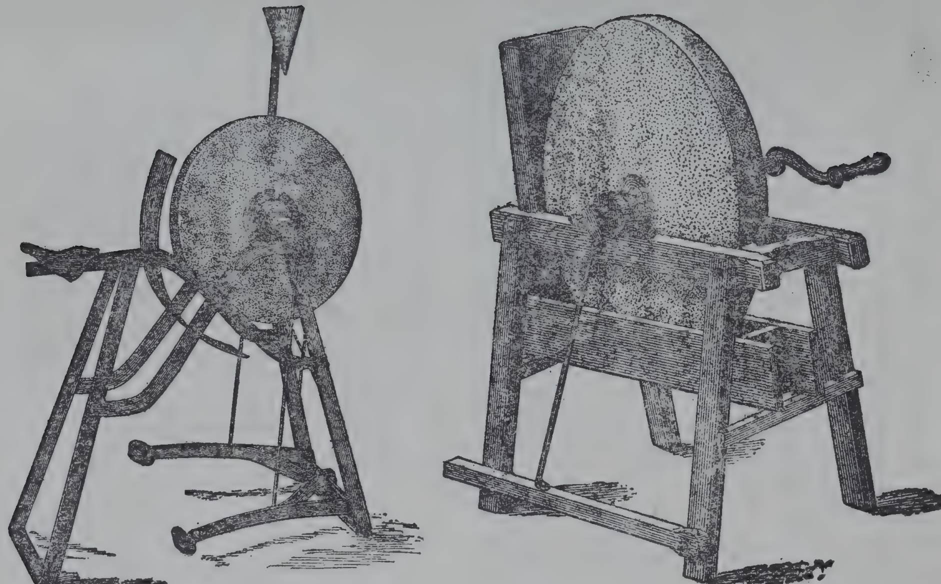


Fig. 113. Two types of grindstone

The tool may be moved back and forth across the stone to keep its face true, but never up and down. This up and down motion is careless and gives the defective edge shown at *b* (Fig. 112) — very bad grinding.

It is an easy matter to test your grinding by occasionally placing the blade of a try square on the bevel. If it is not straight, your grinding needs more care. Too much stress cannot be laid on the importance of this subject of grinding. It is the

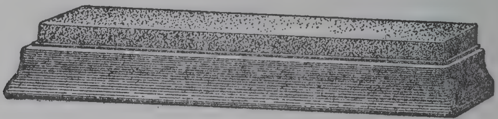


Fig. 114. The oilstone

key-note of success. If you are careless in this particular, your work at the bench cannot be a success. "A good workman is known by his tools."

A teacher of drawing once said, "I don't care to see your drawing; all I want is to see your pencil. I can tell just what kind of work you are doing by observing the care you give your pencil."

This is peculiarly true of the worker with tools. Find a man very particular about them, and you may be sure he is a careful workman.

After grinding comes sharpening. This is done by rubbing the bevelled side back and forth a few

times on an oilstone, lubricated with a few drops of sperm or light machine oil.

The stone should be wiped off, afterward, and should never be saturated with the oil. If this is

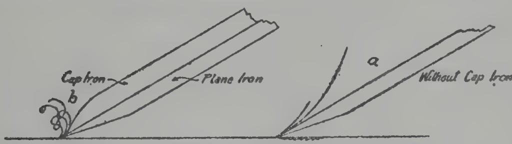


Fig. 115. The action of the cap iron

allowed to happen, the surface becomes gummed (Fig. 114) and loses its cutting edge. This rubbing will sometimes turn over a thin wire edge, which is removed by laying the tool with the flat side on the oilstone and drawing it toward you. The wire edge can be further removed if necessary by stropping on a piece of leather.

Before replacing the cutter in the plane, the cap iron is fastened on the flat side about 1/16-inch from the cutting edge; but this distance may be varied for different woods.

The object of the cap iron is to prevent a splitting action by bending the shaving forward, as shown in Fig. 115. At *a* is shown the effect when there is no cap, and at *b* the splinter bent over giving a shaving.

XI

SQUARING UP STOCK

HAVING prepared Harry for the serious work to come by his explanation of the plane and its operation, Ralph prepared to start his pupil on the most important and difficult problem in shopwork — squaring up stock.

"Anybody," he said "can hack away at a piece of wood with tools, and get some kind of result, but if this work is worth doing at all, it is worth doing well, and to be able to square up stock is perhaps the most important operation you will ever do. It is like mathematics, the answer is either right or wrong. When you finish, the stock is either square or not square.

"To square up stock means to reduce it to three definite dimensions, length, breadth, and thickness, with all adjoining edges or surfaces at right angles. It sounds easy.

"Suppose we want a piece 12 inches x 2 inches x 7/8 inch. First, saw out your stock about 12 1/4 inches x 2 1/4 inches x 1 inch. This allows something

each way for the tools to remove in the process — for sawdust and shavings. It is considerably more than necessary, but on the first trial you waste more than later, when you have become skilled in this work.

"Second. Dress down one of the flat faces with the jack plane; follow with the smoothing plane and test, with straight edge, with the grain, across it, and diagonally across corners. When this face is finished it constitutes the foundation of the process, and is called the 'working face.'

"Third. Make a pencil mark on the working face near one of the edges. This is called a witness mark, and it indicates that the edge it touches is to be the next face dressed.

"Fourth. Dress down the edge, making it square with the working face, and testing its whole length with the try square. This is the 'joint edge' (Fig. 116).

"Fifth. Set the marking gauge, as shown in Fig. 117, holding it in the left hand and the rule in the right, to two inches, the width of the finished piece. The reason for this is that the scale on the gauge stick is sometimes inaccurate.

"With the gauge block against the joint edge, gauge a line the entire length of the working face. In doing this, the gauge may be used in either hand, and

in fact it is well to practise so as to be able to use either at will. The tool should always be pushed from you, and at the same time tilted from you,

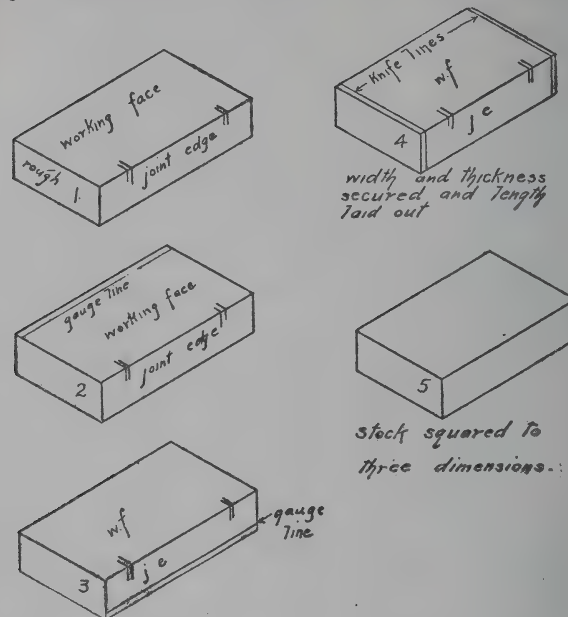


Fig. 116. Steps in the process of squaring up stock

until the steel point makes only a fine line. If it is held upright, the point will try to follow the grain, which is very seldom parallel with the edge.

"You have now laid out on the working face your first dimension — the width.

"Sixth. Plane down the edge opposite to the joint edge, almost to the gauge line just drawn. Remember that the tendency is always to take off too much,

and when a piece is too small there is no way of making it larger, but if it is left a little too large, it is a simple matter to take off one more shaving. In other words, always be on the safe side, and take off too little rather than too much. Test this edge to see that it is square with working face before

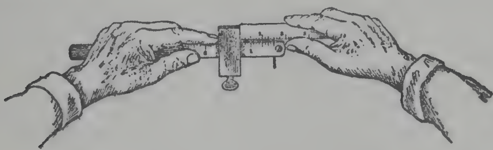


Fig. 117. "Setting" the marking gauge

reaching the gauge line. Get into the habit of marking all high spots with a pencil, and planing out the marks.

"Seventh. Set the gauge at the required thickness, in this case $\frac{7}{8}$ inch — and with gauge block against working face, make a line full length on both of the squared edges.

"Eighth. Dress down the remaining rough face to or near both gauge lines just drawn, and test with straight edge, as in the working face. The stock is now to the second dimension — thickness.

"Ninth. Secure the last dimension — length. As near one end as possible make a line across the working face with a knife and try square, and continue it around the four sides back to the starting place.

If it does not come out exactly at this point, the stock is not square.

"From this knife line, measure off the length on the working face, and square a knife line on the four sides, as on the first end. Block-plane both ends to the knife lines, and test.

"If these nine successive steps are carried out accurately, the answer is correct," as Ralph remarked after Harry had worked faithfully throughout the whole explanation.

The boys realized that they needed a shooting board as a necessary part of their equipment, and after Ralph had worked out the drawing shown in Fig. 118, Harry was told to square up the four pieces of stock to be used in its construction.

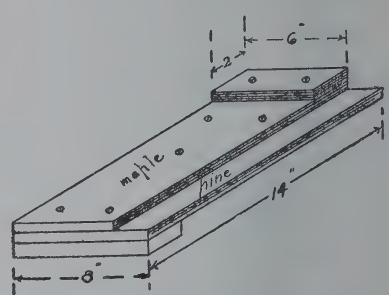


Fig. 118. The shooting board

"Now let me show you a new trick," said Ralph. "It is always a good plan after making a drawing to write out a bill of material something like this:

1 pc. pine 14 x 8 x ½
1 pc. maple 14 x 6 x ½
1 pc. pine 8 x 1½ x ⅞
1 pc. pine 6 x 2 x ½
4 1¼-inch f. h. screws
5 ¾-inch f. h. screws

"There you have in a nutshell all the items needed for the shooting board, and you can proceed to square all your pieces to these dimensions without consulting the drawing until you are ready to assemble the parts. The five ¾-inch screws are for fastening the maple pieces to the flat piece of pine, and the 1¼ screws to fasten the cleats. All the holes for screws are to be bored and countersunk."

"What's countersunk?" asked Harry.

This led to a talk on screws and boring tools, and

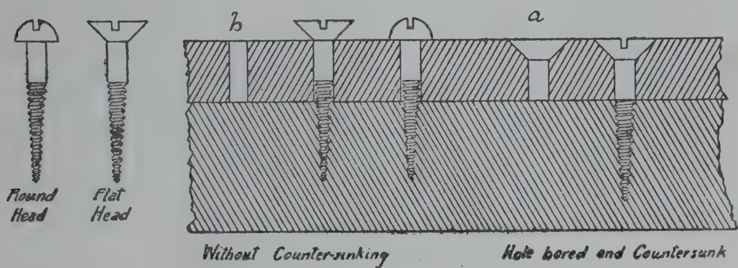


Fig. 119. The use of screws

as it is valuable to the young worker in wood, we will give it as fully as possible.

"There are several kinds of screws," began Ralph, "but the two most commonly used are flat heads and round heads. (Fig. 119). Flat-head screws are those we generally think of, but unless the hole which has been bored or drilled is reamed out at the top, countersunk as we call it, the screw head will

stand out from the surface ready to tear your clothes and to scratch anything it may come in contact with, so you can readily see the importance of sinking them below the surface.

"On the other hand, there are often cases where we have no desire to hide the screw. The round heads are used for such cases, and because of their shape they do not catch hold of things. These screws are usually blued — treated with acid to give them a dull, more artistic colour. Screws treated in this way do not rust as readily as the bright ones. You can buy brass screws in both flat and round head forms; in fact you can get tinned, Japanned, lacquered, bronzed, copper, nickel, and even silver plated screws — if you have the money.

"In buying them, you must always give two numbers — the length, in inches, and the diameter. This is the diameter of the wire forming the body and runs from 0 to 30, number 0 being about 1/16 inch.

"A one-inch screw No. 8 would be fatter or larger in diameter than a one-inch No. 6, which is of comparatively slight or thin proportions. They are sold in boxes containing a gross.

"In fastening two pieces of wood together, they

should be prepared as shown at *a* (Fig. 119) for a flat head and as at *b* for a round head. The screw slips through the first board, and the screw threads engage only in the second in each case."

XII

BORING TOOLS

"BORING tools are very interesting," said Ralph. The brace and bit for soft woods have practically taken the place of the old fashioned augers, gimlets, etc. The reason is not hard to find. An auger or gimlet could bore but one size of hole, while with a brace and set of bits almost any diameter can be secured. A little later on, I'll tell you about a Yankee invention along this line.

"The brace is a sort of universal tool holder, and any tool designed to fit into it is known as a bit, as for example a countersink bit, or a screw driver bit, and several varieties of drills.

"The shank, or part that fits into the brace, is usually square and tapering, and the part of the brace which engages this shank is called the 'chuck.' (Fig. 120.)

"The centre bit, an old-fashioned form, had all the necessary features of a good boring tool but one. It had a sharp centre for accurately locating the

hole, a knife edge for cutting the fibres, and a chisel for removing the wood, but it lacked the spiral screw thread of the modern tool, and had to be forced through the wood by main strength. On a modern auger bit, this spiral screw relieves the worker of a large part of the labour; all he has to do is to turn the brace and keep it straight, supposing of course that the bit is sharp. (Fig. 121.)

Fig. 120. Gimlet bit and centre bit

"The auger bit is most commonly used by woodworkers. It has two knife edges and two chisels besides the spiral spur in the centre. A short form of this tool, called the dowel bit, has the advantage of bending less readily than the ordinary auger bit. The size in sixteenths of an inch is stamped into the metal shank, but if this number is not distinct or for any reason is missing, the diameter may be measured by holding the rule across the knife edges."

Fig. 121. The auger bit

"What's the Yankee invention you were going to tell me about?" interrupted Harry.

"Well, suppose you wanted to bore a large hole, say 2½ inches in diameter, the probabilities are that you wouldn't have a bit that size. In fact, to have a full set of bits from 3/16 inch up to 3 inches would mean a very expensive lot of tools. This difficulty has been overcome by a very clever invention called the extension or expansive bit. (Fig. 122). On this tool the knife edge and chisel are part of a moving lip, which may be fastened at any desired point by means of a set screw.

"Besides being adjustable in diameter, the lip of the bit has a scale, and the body a single line engraved on it. By bringing this line to the various measurements on the scale, you can set it to a definite size without the trouble of measuring it.

"The tool has certain limitations, of course. It is made in two sizes; one will bore holes of any size from ½ inch up to 1½ inches, and the other any size from ⅞ inch to 3 inches, while extra lips or cutters are made to bore as large as 4 inches, but if you ever try to bore a hole of this size you will want all your muscle."

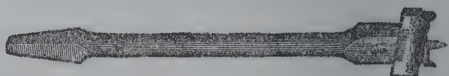


Fig. 122. The expansive bit

The screw-driver bit is simply a screw-driver with a bit shank instead of a wood handle, and the counter-

sink has a cone-shaped end with enough grooves cut in it to give one or more cutting edges. Its use was illustrated in making the bench hook and shooting board.

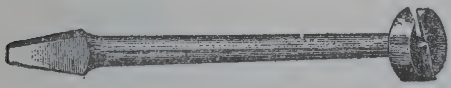


Fig. 123. The Forstner bit

The gimlet bit may be used for boring holes for screws. It is made from 2/32 inch up to 12/32 inch, and is valuable for preparing articles for the smaller-sized screws where the auger bit would be too large.

We find for sale drill bits for electricians, warranted to go through a nail if necessary, and dozens of special bits.

In working with thin wood, the auger bit is very apt to split it, especially brittle woods, like red gum. Even this contingency is provided for in the Forstner bit, which will bore a hole in a sheet of paper (Fig. 123), and is therefore very valuable for work in veneering or other very thin material.

The brace is represented by several styles and makers, but the beginner must look for the same qualities in the brace as he would in any other tool — good workmanship and material, simplicity and durability.

The old-fashioned Spofford brace was strong, simple, and reliable. For working in corners or

any place where a full revolution of the tool is not possible, a ratchet attachment is necessary. This

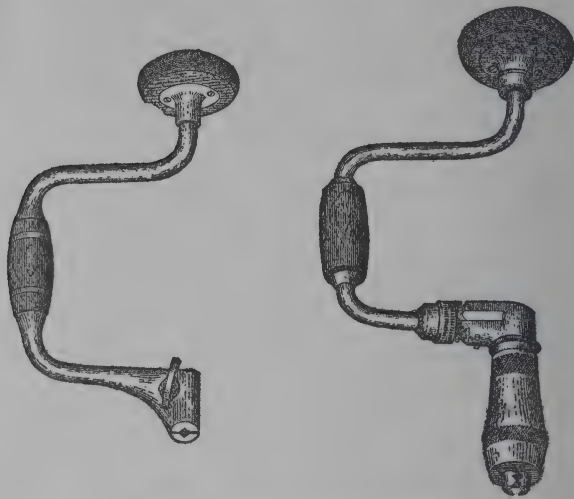


Fig. 124. Common types of the brace

is found on most of the modern tools, and may be obtained at any hardware store. (Fig. 124).

The hand drill (Fig. 125) is one of the most useful tools any one can have about the shop or the house. To be able to make holes in soft or hard wood, tin, zinc, brass, copper, or iron is certainly a great advantage, and some form of the tool should be in every establishment. Our boys found it useful in making moving toys, wind vanes, anemometers, and dozens of other pieces, and never regretted its cost. It may be bought for fifty cents and upward, a very

good one costing about $1.50. The drills designed to be used with this tool vary by 1/64 inch, beginning

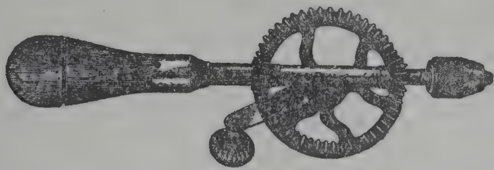


Fig. 125. The hand drill

with 5/64 inch up to 3/8 inch. Above this a larger chuck is required. They have round shanks instead of the ordinary square bit shank.

XIII

MISCELLANEOUS TOOLS

THE SCREW-DRIVER

THE need of a screw-driver is too obvious to require special mention. They are made with blades from two inches up to thirty inches long, and have round, flat, or corrugated handles. The best grip is obtained on either a flat or corrugated one, and two sizes are desirable, a small one with about a three-inch blade, the other with an eight or ten. (Fig. 126.)

Some of the magazine brad awls containing a dozen awls and screw-driver are very convenient, but the combinations supposed to contain a whole tool outfit, including saws, are poor investments.

Ratchet screw-drivers, from which the hand is not removed during the operation of driving or withdrawing a screw, are on the market, but they are luxuries rather than necessities.

Pliers with wire-cutting attachments are convenient, and should be added to the kit when possible; some of

them are powerful enough to cut a heavy wire nail. (Fig. 127.)

The Mallet. This simple tool is made in a dozen different forms for various trades. The round-headed kind is perhaps the cheapest. It is made of hickory or lignum vitæ. (Fig. 128.)

Fig. 126. Screw-drivers

The best form for woodwork has an oblong or square head of lignum vitæ. The handle should pass clear through the head and be fastened with a wedge.

A blow from this tool does not shatter the tool handle as would a blow from a hammer. A comparison of the two blows might be likened to the action of gun powder and dynamite. The slow burning powder represents the action of the mallet. The hammer should never be used on a chisel or gouge.

Fig. 127. Pliers

Hand screws for holding glued-up work together, sometimes for holding special work on the bench top, are made of wood, with either wood or metal spindles. For ordinary work, the jaws

should be parallel, but special forms are on the market which will hold irregular forms, as shown in Fig. 129.

They are made in several sizes, from little ones with 4-inch jaws up to 22-inch jaws. For large and heavy work, clamps of wood or metal may be had as large as eight feet in length. They are useful in the making of drawing boards, doors, etc., but are not a real necessity for boys' ordinary woodwork. Clamps in the form of trestles for specially important large work are made as large as twelve feet in length.

Fig. 128. The mallet

For ordinary purposes, a pair of 6-inch and a pair of 12 or 14 inch wood hand screws will answer. The ingenuity of the young woodworker will suggest other ways of holding glued-up work in the absence of hand screws, such as winding with heavy twine or rope, and twisting a stick through the strands, after the old method of tighten-

ing a buck saw or turning saw. In building up a drawing board and gluing the strips together, the requisite pressure may be obtained by laying it on the floor between blocks temporarily nailed there, and wedges driven in, after the method described for picture frames.

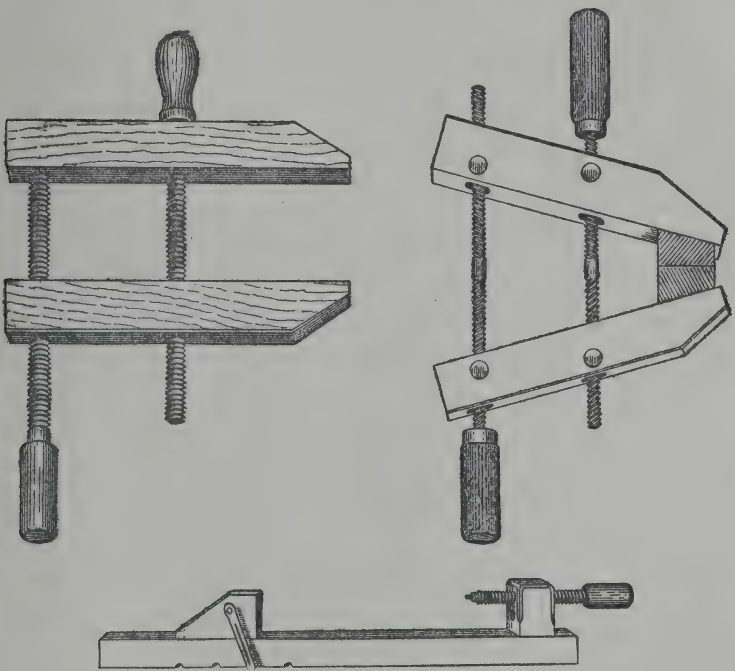


Fig. 129. Clamp and hand screws

A large part of the value derived from woodwork is in the exercise of ingenuity required to meet unexpected contingencies. Just so the owner of

an automobile learns more about mechanics and the construction of his machine by being obliged to make repairs on the road, miles from any repair shop, and with a limited number of tools and appliances.

THE HAMMER

This common tool is made in at least thirty different forms, and some styles in nine or ten different weights. For woodwork, the adze-eye claw hammer, weight sixteen ounces, will answer all requirements. For use with brads as small as ⅜ inch, a brad hammer of three or four ounces is desirable. Both of these forms are provided with claws for withdrawing nails. (Fig. 130.)

Fig. 130. Hammers

Claw hammers are comparatively modern inventions, and there are men now living who, when serving their apprenticeship, were obliged to withdraw their nails with a pair of pinchers. At that period all nails were wrought by hand, and houses

are standing to-day on which the clapboards are still held in place by nails forged on an anvil by hand.

THE FILE

A volume might be written about the various shapes, sizes, and methods of cutting of this tool. Its place in woodwork is limited, and it should never be used where another tool will do the work. Like sand-paper, it has a tendency to lead to bad habits and slovenly work. On certain pieces of curved work in hard wood it may be used to remove the sharp edges left by chisel or gouge, especially the latter, but its action even there is apt to tear away the fibres.

An eight-inch, half-round, cabinet wood file and an eight-inch, round, slim No. 0 cut Swiss pattern file are sufficient.

For sharpening bits, a special auger bit file is made, and this may be used for sharpening the marking gauge point and such small work. For sharpening saw teeth, triangular saw files are sold at all hardware stores.

THE SPIRIT LEVEL

This is necessary on outdoor structures which are to be placed on foundations, in securing level or horizontal timbers, and in plumbing the uprights.

The human eye is not equal to the task. Masons and builders make use of wooden plumb rods, but

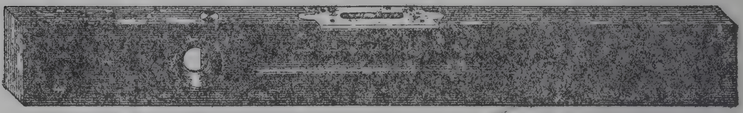


Fig. 131. The spirit level

as the level is necessary to secure the horizontals, it will be at hand for the uprights, the two glass tubes being at right angles. (Fig. 131.)

RULE

A two-foot, four-fold, boxwood rule, graduated to eighths outside and sixteenths inside, will answer all ordinary requirements. (Fig. 132.)

THE STEEL SQUARE

This simple but valuable tool, about which volumes have been written, is necessary for building construction, but is not needed in the making of furniture or cabinet work.

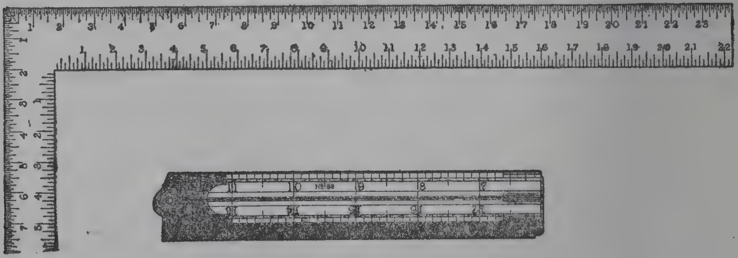


Fig. 132. Steel square and rule

XIV

BIRD HOUSES

THE boys felt that they were ready for business, and Ralph suggested that they had studied tools long enough, and now had better get busy and make something.

The cat, that arch enemy of the native birds, had driven the robins, martins, and wrens all away. Each year some of these brave little birds started homes in the trees near the house only to have their families devoured as soon as they were hatched.

A bird house to be attractive need not be very pretentious, but it must absolutely be cat-proof, or the birds will inspect it carefully from all points of view and leave it severely alone. A nest well hidden in the tree foliage or shrubbery is not nearly so conspicuous as a brightly painted house fastened to the limbs of a tree. The side of a barn or outhouse, far enough down from the roof so that the cat cannot reach it, or a tall pole covered on the upper part with tin, so that the feline bird hunter cannot gain a foothold, are about the only safe

places for a house which the birds will actually adopt. The first house our woodworkers manufactured is shown in Fig. 137.

This was a single or one-family house, and its construction was very simple.

The list of material follows:

One pc. ½-inch pine or white wood 10 x 6½ ins.
Two pcs. ½-inch pine or white wood 7½ x 3 ins.
One pc. ½-inch pine or white wood 9½ x 5 ins.
One pc. ½-inch pine or white wood 9½ x 4½ ins.
Two pcs. ½-inch pine or white wood 5¼ x 4½ ins.

The first piece, 10 x 6½ inches, was simply squared up for the bottom. The two pieces for the sides, 7½ x 3 inches, were squared up, and one edge of each planed to a 45-degree bevel, to engage with the roof boards.

The latter were squared up, and nailed together at right angles with 1¼-inch brads.

The two ends, 5¼ x 4½ inches, were carefully laid out as shown in the drawing, sawed, and planed to the lines with square edges.

In the end which was to contain the circular door a hole 1¾ inches in diameter was bored with its centre two inches from the bottom line. This required the services of the extension bit, and, to avoid splitting the wood, as soon as the spur of the

bit showed on the further side, the wood was turned about, and the hole finished from the other side.

The house was next turned upside down, and fastened in the bench vise. Holes were drilled along the sides of the bottom piece ¾ inch in from the edge — three on each side — countersunk, and

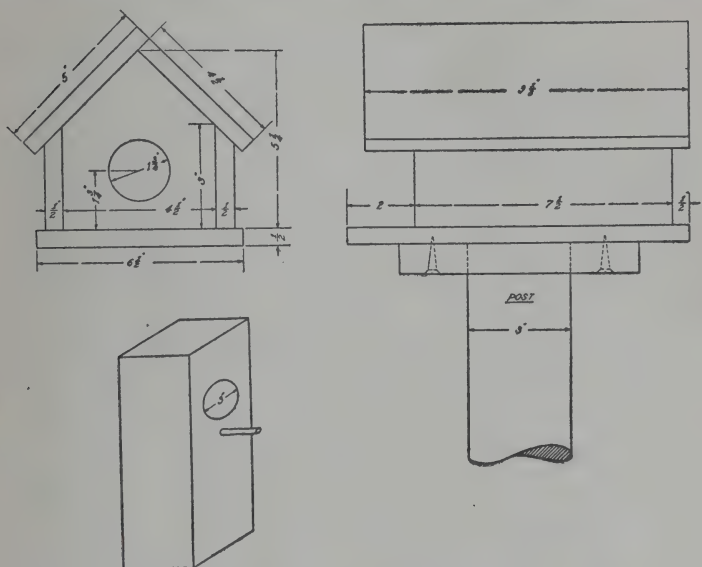


Fig. 137. One family bird house, and house for high-hole

the piece fastened to the sides with 1-inch No. 8 screws. The top pieces already nailed together were now nailed in position on the sides and ends with 1-inch brads.

The pole they used was 13 feet long and about 3

inches in diameter at the small end. It was rounded at this end by using a draw knife. (Fig. 138).

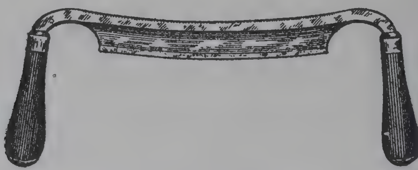


Fig. 138. The draw knife

A block of 7/8-inch pine was bored out, and fitted snugly over the end of the pole. This block was then removed, and four holes bored through it for screws.

Before replacing the block on the top of the pole a cut was made across the end of the pole about two inches deep, by means of the rip saw.

The block was replaced, and wooden wedges driven into the saw cut. This fastened the block securely on the end of the pole, and after making sure that it was level, the bird house was fastened to the block by four 1¼-inch screws from the under side.

A piece of sheet tin was wound around just under the house to discourage pussy, and the pole set into the ground about three feet, bringing the under side of the house ten feet above the ground.

A double or two-family house of similar propor-

tions was built next, as shown in Fig. 139. The list of material called for:

One pc. ½-inch wood 18½ x 6½ (bottom)
One pc. ½-inch wood 18½ x 5½ (roof)
One pc. ½-inch wood 18½ x 4½ (roof)
Two pcs. ½-inch wood 15½ x 3 (sides)
Three pcs. ½-inch wood 5¼ x 4½ (ends and partition)

The construction was the same as before, each end having a door, and the partition of course being solid. The block for supporting the house on the pole was larger, being 8 x 5 x 1¼ inches, and called for six 1½-inch No. 10 screws, to secure it to the under side of the floor. Harry wanted to make it more complete by adding a small wind vane, but Ralph said it might frighten the birds, so it was omitted.

Of course larger and more ornamental houses may be built, but where there are too many families in such close proximity there is apt to be trouble, while houses that are too conspicuous do not appeal to the beautiful American wild birds that we want to attract. With the English sparrow it does not matter so much. For these birds, a tenement house against the side of a barn may be built easily, in the form shown in Fig. 139.

This may be made any length, each door leading

to a compartment separated from the others by partitions. Make as many pieces plus one as there are to be compartments, apartments, or flats; have the bottom project as shown in side view for a perch and walk, and have the roof also project to shed rain.

If not fastened from the inside of the barn by stout screws, this house must be secured to a shelf, or by brackets.

The side view shows a simple shelf made of a

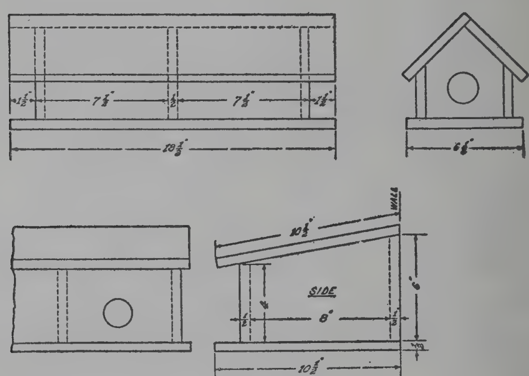


Fig. 139. Two family house and tenement

back piece secured to the side of the barn by screws or nails, a plain shelf nailed to this back piece, and two wooden brackets. If iron brackets are used, both the shelf and back piece may be omitted, the

brackets being fastened to the under side of the bird house and to the siding of the barn by screws.

For birds like the high-hole, or flicker, a piece of hollow log, or an elongated box fastened securely to the side of a pole, made cat proof, is very acceptable. This should not be painted, but should be provided with a door on the side and a perch. (Fig. 137.) The opening should be about three inches for these large birds, and the location should be as secluded as possible. Any number of devices will suggest themselves, but always remember the cat, and study the location from the bird point of view. The martins and swallows are especially to be encouraged, as they are wonderful destroyers of insects.

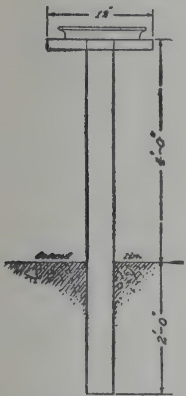


Fig. 140. The bird bath

One device, especially grateful to these feathered friends in hot weather, is a pan of water, in a place where they can drink and bathe without being eternally on the watch for that crouching enemy, who is always stalking them — Tabby.

A pedestal with a platform about four feet above the ground will do nicely, and it can be placed so

close to the house that you can watch them, and enjoy their ablutions almost as much as they do. (Fig. 140.)

The construction is too simple to require an explanation.

XV

SIMPLE ARTICLES FOR HOUSEHOLD USE

THE boys thought it was about time to pay some attention to the wants of the family, who had been clamouring for weeks to have this article or that for the kitchen, dining room, and in fact for every part of the house.

Ralph was a wise teacher, however. He knew that the cause of ninety out of every hundred failures was due to the young mechanic's trying some problem too far advanced.

It seems strange that people cannot learn this lesson. We have seen hundreds of boys led along, say in carving, from one simple lesson to another, until at the end of five or six carefully graded exercises, these boys could carve beautifully any design given them.

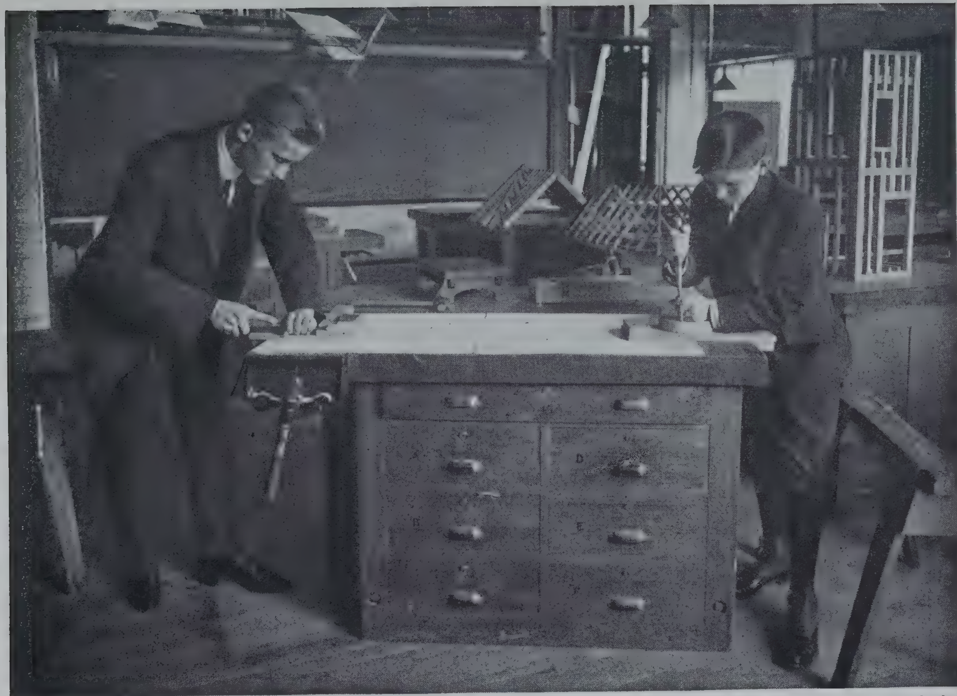
On the other hand, we have seen boys start in on their own hook, without any direction from older people, and ruining everything they tried, simply because they wanted to do the most difficult thing first, before they had developed any skill.

Ralph was determined that his pupil should be an expert and successful user of tools, so he paid no attention to the clamours of the family, and allowed Harry to make only those things which were within his power to do well. Each time a piece of work was finished, and inspected by the family, the universal chorus was something like this:

"Well, if he can make such a fine bird house, I don't see why he can't make half a dozen picture frames for these water colors," or, "If he can make such a fine pen tray, I don't see why he can't make a new stool for the piano!"

In vain Ralph explained that these things could be made in due time, that a picture frame required much more skill than a bird house, etc.

Their household articles commenced with a bread board for the kitchen. (Fig. 141). This gave Harry his first experience in planing a broad surface. He used jack and smoothing planes for the working face, and squared the rest of the board as he had smaller pieces. This required some time. The wood about the semi-circular top was removed with saw and chisel, the board held for the chiselling flat on the bench hook. After getting this curve as true as possible with the chisel, it was finished with a sand-paper block. A ½-inch hole was bored at the



Photograph by Arthur G. Eldredge

Using the Veining Tool

centre of the semi-circle to hang it up by, and the two lower corners were rounded with chisel and sand-paper. No sand-paper was used on the flat surface, as Ralph explained this was a board for cutting

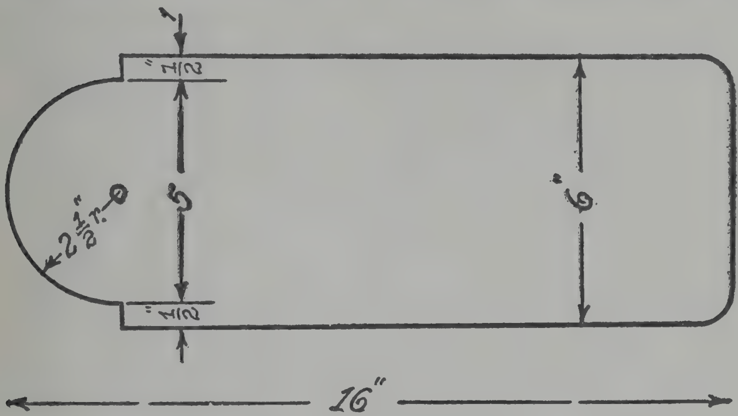


Fig. 141. The bread board

bread, and the grit from the sand-paper would become more or less embedded in the wood, and it would spoil the bread knife. Sand-paper is made of ground quartz, and it soon dulls the edge of a cutting tool.

The knife and fork box (Fig. 142) brought new problems. The list of material was:

1 pc.	11½ x 3¼ x ½	2 pcs.	7 x 1½ x ½
2 pcs.	14 x 1½ x ½	1 pc.	12 x 6½ x ¼

It was made of white wood, and, after being assembled, was stained a rich brown by receiving two coats of bichromate of potash. This is a chemical,

which may be bought at a paint or drug store in the form of crystals. These are dissolved in water, until the solution looks like pink lemonade. It can be applied with a brush, but each coat must be allowed to dry completely before the whole is sand-papered smooth with No. 0 sand-paper. A deeper brown can be obtained by adding one or two extra coats of stain.

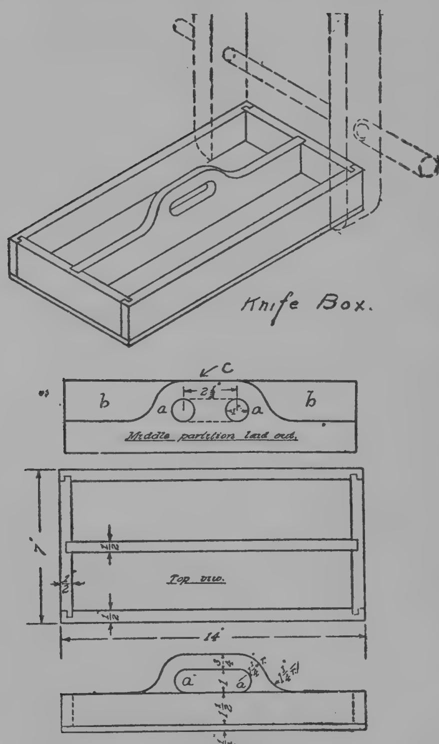


Fig. 142. Method of using hand screws in the construction of a knife box

The middle partition containing the handle was made first. The drawing was laid out on the wood after it had been squared up, and two holes 1 inch in diameter were bored out at *a a*. The wood between was taken out with a key-hole saw, and finished to the line with chisel and knife. A turning saw can be used to advantage on this handle, but it is

not absolutely necessary. Spaces *b b* were removed in the same way, but a knife was used in the concave part of the curve. If it is handy, a small spokeshave can be employed on the whole upper line of this handle.

Anything in the nature of a handle should be rounded to fit the hand. Edges *c c* were therefore rounded with the knife, and finished with coarse, followed by fine, sand-paper.

The two sides were laid out together as in the nail box, and the groove cut with back saw and $\frac{1}{8}$-inch chisel.

The end pieces were made in a similar manner, and the bottom piece squared to $\frac{1}{16}$-inch of finished size. The assembling consisted of first gluing together the sides and ends. Two hand screws were used to hold them. This was Harry's first attempt at using hand screws, and Ralph showed him the importance of keeping the jaws parallel.

The box remained in the hand screws over night, and the next day it was found to be securely fastened. The most convenient kind of glue for boys is the liquid sold in cans. It is always ready for use, and very handy where only a moderate quantity is needed.

Dry glue in the form of flakes, or granulated,

must be soaked over night, and then heated in a pot having a double bottom with water in the lower part.

It should be put on hot with a brush or a small flat stick. The best glue is none too good, yet a good quality has wonderful holding power and should last indefinitely.

After removing the hand screws, the unfinished box was placed in the vise, tested with the edge of the plane, and made perfectly true, top and bottom.

The ¼-inch bottom piece was now put on with one-inch brads, the sides and ends made square, the handle partition slipped into the grooves, and fastened with two brads at each end.

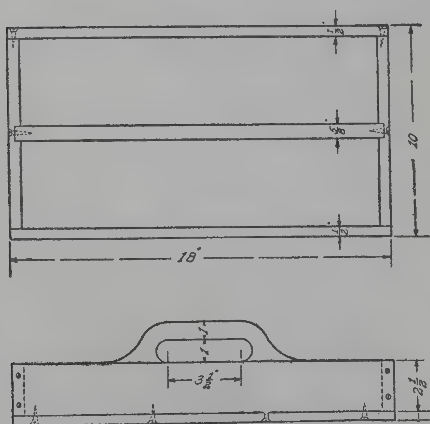


Fig. 143. Tool box

This knife box was so satisfactory that our young carpenters resolved to have a large one for tools. Whenever they had a job to do in the house, they were constantly running out to the shop for something, so that a tool box became a necessity.

The construction was similar to the knife box; but this was larger and heavier, and the dado joints at the ends were replaced by a butt joint fastened with flat-head screws. (Fig. 143). The bottom and

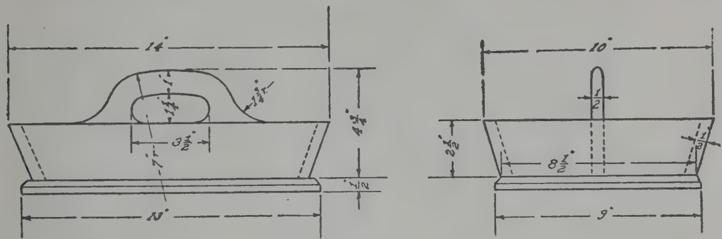


Fig. 144. Another tool box

partition were also put on with screws, on account of the weight to be carried.

These tool boxes are frequently made in the shape shown in Fig. 144, with sloping sides and ends called the hopper joint; but aside from the tool practice it affords, it is doubtful if the shape has advantage enough over the other form to warrant the extra time it takes. Man is an imitative creature, however, and what one carpenter has, the others copy.

The principal features about this useful article should be size and strength, especially in the handle, which should be of about ⅝ or ¾ inch stock.

XVI

THE MITRE BOX AND PICTURE FRAMES

IT SEEMED to Harry that the shop was fairly well equipped, but Ralph insisted that they must have a mitre box before making anything else for the house.

The mitre box is, or should be, an instrument of precision, and although simple in construction, must be perfectly accurate, or it is useless. (Fig. 145.)

The illustration shows the common form, but elaborate affairs of iron and wood can be bought ready made. Every boy should make his own, for the practice, if for nothing else. The sides should be made of oak $7/8$ inch thick, 18 inches long, and $3\frac{1}{2}$ inches high, the bottom of $7/8$-inch pine or other soft wood, the same size.

When squared up, the two sides must be tested by standing them side by side; then reverse one end for end, to see if they are alike. If not, find where the trouble is, and correct it.

It is especially important that the edges of the bottom piece be square and the sides perfectly

parallel. This test can be made with the marking gauge. Sides are fastened on by boring and countersinking for three screws on each. After assembling,

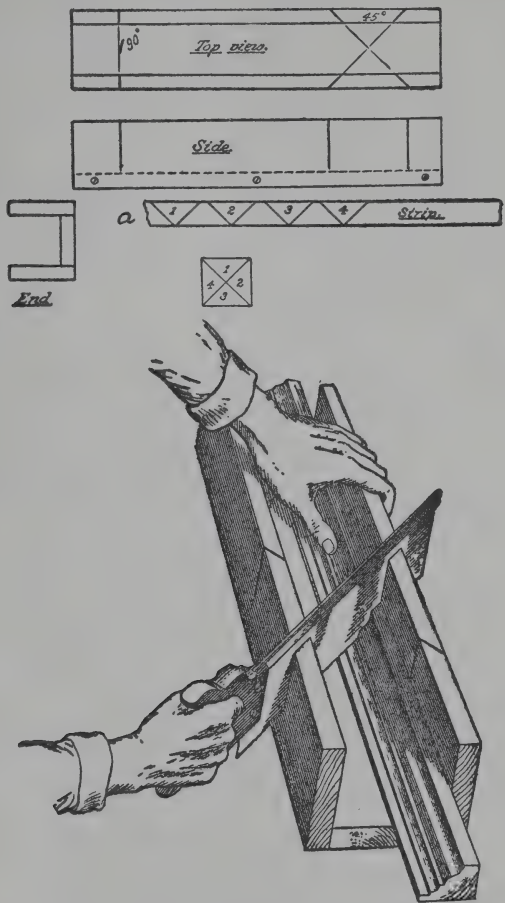


Fig. 145. The 45° mitre box and test pieces

the whole thing must be tested as if it were a solid block. Top edges must be true and parallel.

Near one end — about two inches in — lay out across the top with try square a line 90 degrees with the sides. Carry the line down each side, square with the top edges. For 45-degree angles, lay out a square by drawing two pencil lines across the top, as far apart as the finished mitre box is wide. Draw the two diagonals and square lines from their ends down both sides, taking care that their position is not over the screw in the bottom; because as the saw cuts deeper it may reach this screw and ruin its teeth.

Make the three saw cuts directly on the lines laid out with a cross cut or back saw, with the utmost care. If this is not done accurately, all the labour of preparation is wasted. The blank end of the mitre box may have an additional 90-degree cut, or be left for new cuts in the future, as a mitre box of this description wears out and becomes inaccurate.

Other angles may be used, as 60 degrees or 30 degrees, but it is better to have these on another box as they are used less, and for special purposes. (Fig. 146.)

The mitre box is not ready to use until it has been thoroughly tested. Prepare a strip of soft wood — pine or white wood — 1½ inches wide and ½ inch thick. Cut four pieces from it on the mitre box, using the back saw as shown at *a*, with only one of

the slits. Place these four triangular pieces together to form a square. All the four mitre joints of this square must fit perfectly. If they do not, mark the slit "N. G.," and test the other slit in the same way. If all right, mark "O. K." It often happens that one may be perfect and the other inaccurate. If they are both O. K., the box is ready for use. If one slit is useless, lay out and cut another on the blank end of the mitre box in the same direction, and test again.

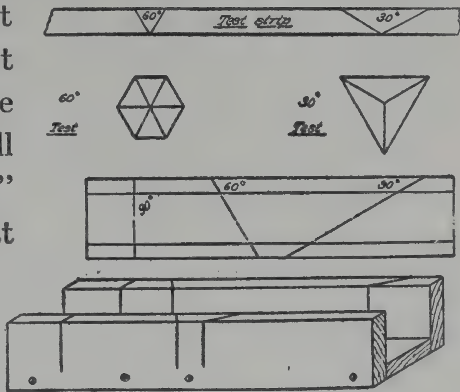


Fig. 146. 30-60-90 mitre box

In testing a 30-degree cut three pieces of the strip should be sawed out, and when placed together they should form a perfect equilateral triangle, while from a 60 degree cut, six pieces are needed to form a hexagon.

These angles are valuable in inlaid work, and for getting out geometrical designs.

The 45-degree cut is indispensable in making the mitred corners of picture frames and in cabinet work.

In making picture frames of simple cross section, it is first necessary to cut the rabbet (Fig. 147) with a rabbet plane. If this moulding is made by hand, the size of the picture should be measured, the length of all four sides added, and a liberal allowance made for waste.

In the figure, the triangles *a a* are waste, the

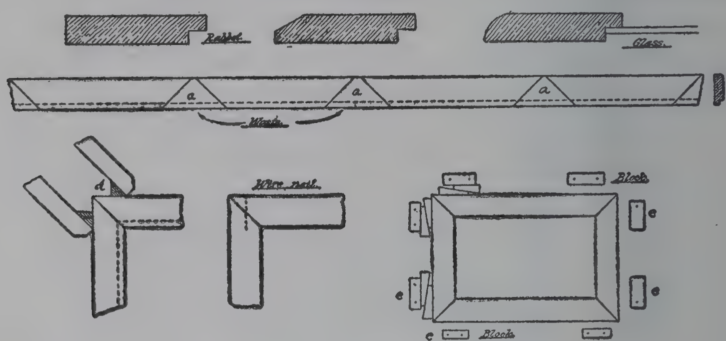


Fig. 147. Making picture frames

rabbet being indicated by the dotted line. After the four pieces have been sawed out on the mitre box, they should be placed together on a flat surface, such as the bench top or floor, to see if the mitres fit perfectly. If they do not, one of them can be block planed to make a perfect fit, and the other three laid close together, as shown in the illustration.

The assembling is the hardest part of the operation, and many devices have been tried and some patented to hold the parts together while the glue is drying.

Perhaps the surest way is to drill a hole in one piece of each joint large enough for the passage of a wire bung-head nail.

The undrilled piece is placed vertically in the vise. The drilled piece, after receiving a thin coat of glue, is brought into position horizontally, and the nail driven home.

Theoretically, the nail should catch at the first blow, but the horizontal piece will sometimes slip, even with the best of care. It is wiser to place this piece about 1/16 inch above its final position, to allow for this slip.

A method sometimes used is to glue near the ends of each piece a triangular block of wood, as shown at *d*. These must be left over night to harden.

The next day the whole four pieces can be glued and held together by four hand screws, as shown, until the glue is thoroughly hard. This method, of course, can only be used with plain moulding or that which is square on the outside.

Our boys tried another way that is commonly practised. They nailed oblong blocks to an old drawing board, as shown at *e e*, and then placed the picture frame in the centre, after gluing the joints, and driving wedges in between the blocks and the

frame. Paper placed under each joint prevented the frame from being stuck to the drawing board by the glue forced out by the pressure.

This paper plan was learned by experience, as the first frame the boys tried had to be pried up from the board, and in so doing they broke it at two of the joints, so that it had to be made again.

It is well to remember in gluing mitre joints that end grain absorbs more glue than a flat surface. A priming coat should be applied first, and allowed to remain a few moments to fill up the pores. The second coat should hold fast and make a strong joint, but an excess of glue should always be avoided, as it must be removed after hardening, and glue soon takes the edge from the best of tools.

Very fancy frames should be avoided. A bevel on the outside or inside, or both, is about all the young woodworker should attempt in the way of ornamentation. Depend on the natural beauty of the wood, as a fancy frame draws the attention from the picture, which after all is the main thing. We should admire the man, not his clothes, the picture not its frame, although the latter should be neat and well made.

The finishing and polishing of frames is taken up in a following chapter.

XVII

MAKING TOILET BOXES

TO MAKE a wooden box sounds like a simple proposition; but in making the drawing, the questions of size, proportion, joints, hinges, etc., immediately come up.

The size of course depends on the purpose of the box. If it is for ladies' gloves, it should be long and narrow; if for collars or handkerchiefs, square or nearly so. The height is nearly always made too great. In fact, the whole question of proportion is one which can hardly be taught; it must be felt, and different people have different ideas as to what constitutes good proportion.

Some hints, however, may be given: A box perfectly square does not look well. Again, dimensions that are multiples do not look well. A box 4 x 8 x 12 inches would not be nearly so pleasing as one 3 x 5½ x 12 inches.

The proportions are also affected by the constructive details. Is the box to be flat on the sides and ends or is the top to project? etc.

Our boys argued and sketched and finally drew the design shown at Fig. 148. This was to hold ties. The top was to project and have a bevel, or chamfer, also the bottom. No hinges were to be used, but the cover was to have cleats fastened on the under side to keep it in place, and to prevent warping.

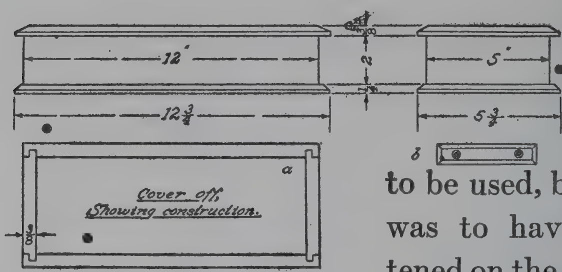


Fig. 148. Dado joint used in box design

The next question was the manner of fastening the sides and ends. On unimportant work, a butt joint with glue and brads can be used, but for a toilet article, the holes made by the brads, even if they are filled with putty, are not satisfactory.

So it was decided to use the dado joint as shown at *a*. This meant more fine work, but, as Ralph suggested, it was to last a lifetime, and should be made right.

Sides and ends were squared up, and the grooves on the side pieces laid out as in the best work. The rabbets on the end pieces were cut out with the back saw and chisel. After the joints had been carefully

fitted, the four pieces were glued together and placed in hand screws over night.

While the glue was hardening, the two pieces for the top and bottom were squared up and bevelled with the smoothing plane on the long sides, the block plane on the ends.

The cleats for the top were next made, drilled and countersunk for the screws as at *b*.

A careful full-sized drawing of half of the top was made, and a chip carving design drawn for it. The cleats were not put on until the carving was finished and short screws had to be used so they would not come through and spoil the surface.

The next day the body of the box was removed from the hand screws and squared with a smoothing plane. The top and bottom were put on with 1-inch brads. These were "set" with a nail punch to prevent any possible scratching and the whole box was rubbed down with wax dissolved in turpentine.

For fine cabinet work, the dovetail joint makes the most satisfactory method of fastening, but Harry was not yet skilled enough to do the fine work it demanded.

The second box was for handkerchiefs, dimensions 8 x 7 x 3 inches outside, and no overhang at either

top or bottom. The construction brought in several new features. Sides and ends were dadoed together as in the first box.

The top and bottom, after being squared, were rabbeted on all four sides until they fitted snugly into the opening top and bottom. They were glued in these positions and placed in hand screws over night. (Fig. 149.)

"How are you going to get into that box?" asked Harry. "You've closed it up solid and glued the top on."

"Wait and see," was all the satisfaction he got.

The next day the hand screws were removed and the box squared up exactly as if it had been a solid piece of wood. Ralph then made two gauge lines

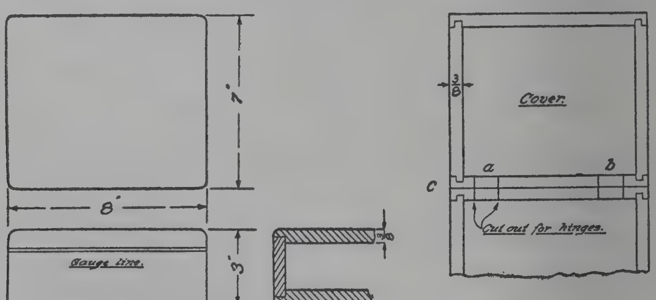


Fig. 149. The handkerchief box

around the four sides, ¾ inch from the top and ⅛ inch apart. Then he cut the box in two between these two lines with a rip saw, after slightly

rounding all corners except the bottom ones with a plane and sand-paper.

By this method, the box and cover must be exactly alike in outline, and by planing to the gauge lines, they will fit perfectly.

It only remained to hinge the two parts together, but this operation proved to be no slight task.

The body was placed in the vise and the cover laid upside down on the bench top. The two parts were brought together as shown at *c*, and the four knife lines laid out as shown with knife and try square.

The distance between the lines at *a* and *b* must be equal to the width of the hinge, and the wood between these lines removed to a depth equal to half the thickness of the hinge at its joint when closed. If too much is removed, the box will be "hinge bound" and will not close in front. If too little is taken out, it will close in front and have an open joint at the back. In the former case, a thickness or two of paper placed under the hinge will often be enough to make it close in front. In the latter case, of course more material must be cut out. It is a delicate operation, as the depth of these cuts for 1-inch hinges is only about 1/16 inch. It is a question of accuracy, pure and simple.

Holes for the screws can be made with a brad awl.

The boys made several boxes of various sizes and styles, some plain, some decorated with carving. Pyrography, or burnt work, is frequently used for decoration, and the best wood for this purpose is basswood, because of its white color, softness, and freedom from pitch. Other woods may be burnt, but pine, which has veins of pitchy sap, is not suitable.

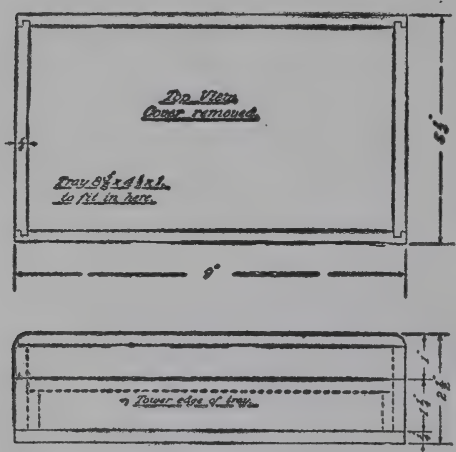


Fig. 150. A box for drawing instruments

A box for drawing instruments is shown in Fig. 150. Its outside dimensions are 9 x 5¼ x 2½ inches. Our boys made theirs of gum wood because of the beauty of its colouring and its suitability for carving. The joints used and the method of construction were the same as in the handkerchief box, but it was provided with a tray for the instruments. This was one inch deep over all, and rested on two thin strips fastened to the ends inside.

These strips were $4\frac{1}{4} \times 1 \times \frac{1}{4}$ inches, and, by raising the tray one inch from the bottom, left a space convenient for holding triangles, protractors, pencils, etc. The cover was decorated with a border and centre piece in chip carving.

The making of dovetailed boxes is taken up in a following chapter.

XVIII

BRACKETS AND BOOK RACKS

BRACKETS are often required about the house for many purposes, and their size, shape, and decoration are infinite. There is even more fun in designing them than in making them. Tastes differ in this respect, as in everything else, and, given the problem, no two people will bring out the same design unless they simply copy something they have seen, which is not designing.

When our boys started to make brackets in response to urgent demands from the family, Ralph blocked out the sketch shown in Fig. 151 at *a*.

"There is a bracket," he said; "it consists of three pieces, and properly put together it will hold what it is designed to hold. It is not a thing of beauty, and we must improve it. How? By changing its outline without impairing its strength. In other words, we must '*design*' a bracket constructed of three pieces of wood put together at right angles. There's your problem; now take paper and pencil and let us see what you can do."

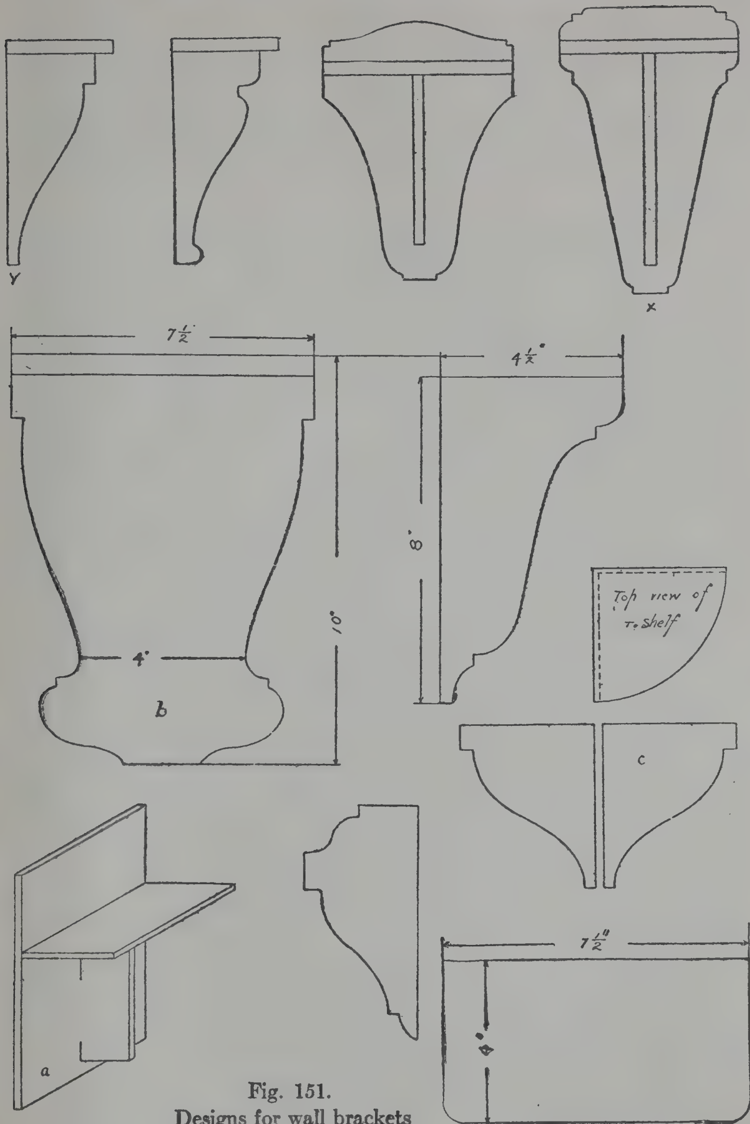


Fig. 151.
Designs for wall brackets

"What size?" asked Harry.

"Oh, in this case, I'll leave it to your judgment."

For fully an hour, no sound was heard in the shop but that of two lead pencils. Harry was getting experience.

"Let me give you a pointer," said Ralph. "Don't try to draw both sides alike, as it is very difficult where you have free-hand lines. Draw a vertical line representing the centre. Sketch one half of the design, and when you have it about right, fold the paper on this centre line and trace the other half.

Harry went to work again and at the end of another hour produced the sketches shown in Fig. 151.

Ralph criticised them all rather severely, and as Harry was tired, this treatment made him sulky.

"Don't get mad," said Ralph kindly; "you know designing is hard work and the only way you can learn is to have me help you by pointing out your weak spots. Artists are obliged to pay for criticism; you know I'm not finding fault."

"All right," said Harry, brightening up, "which one shall I make?"

"I think the one marked *x* is the best. Work it up more carefully, design the shelf and bracket and put on all the dimensions."

"The bracket? Why, what is this I have drawn?"

"That's the back piece that goes against the wall; the bracket piece supports the shelf, and remember when you make it in wood, the grain must always run the long way of each piece.

"Why?"

"I'll show you," said Ralph.

He cut out two pieces of wood about 8 x 1 x ½ inches, one with the grain running lengthwise and on the other the grain running the one-inch way. Handing the first piece to Harry, he said, "Let me see you break it with your hands."

The boy tried and failed. Handing him the second piece he said, "Now try this."

It broke so readily that Harry was astonished.

"That's why," said Ralph, "and that's all."

The three pieces as finally drawn are shown in Fig. 151 at *x*. They were all cut out of gum wood with a coping saw, finished to the lines with chisel, spokeshave and sand-paper block, and put together with ¾-inch brads. The nails were driven through the back into the bracket, the latter piece being held in the vise in a horizontal position. It was then shifted to a vertical position with the back piece to the left of the vise and the shelf nailed to the bracket. Two brads were also driven through the back into the shelf.

Brackets may be ornamented in many ways; by chip carving, pyrography, or by staining, but the decoration should be put on before assembling.

Another form is shown at *b* in which the back piece is not carried above the shelf, the latter piece resting on the top of the back. From a constructive standpoint this is a stronger form than the other, as part of the weight is carried by the back instead of by the brads alone.

Corner brackets are sometimes used and may be made in the form shown at *c*. Here we have two wall pieces and a V-shaped shelf, the V being a right angle. Again, the form may be so long as to require two brackets and it may then be considered a shelf.

In fastening any of these forms to a plastered wall, considerable care must be taken in placing the nails or screws so that they will engage in a stud instead of just in the plaster. The location of the studs can be found by tapping on the wall with the knuckle or lightly with a hammer. A surer way, however, is to find the nails in the picture moulding or base board and plumb from either of these places with a small weight — such as a nail — on a string.

The designing and making of book racks offer an almost endless field for the imagination. The

rack may have a fixed length or be adjustable and either of these forms may have fixed or folding ends, and again the shapes of the ends may be varied in form and decorated in several ways.

Perhaps one of the simplest forms of folding book

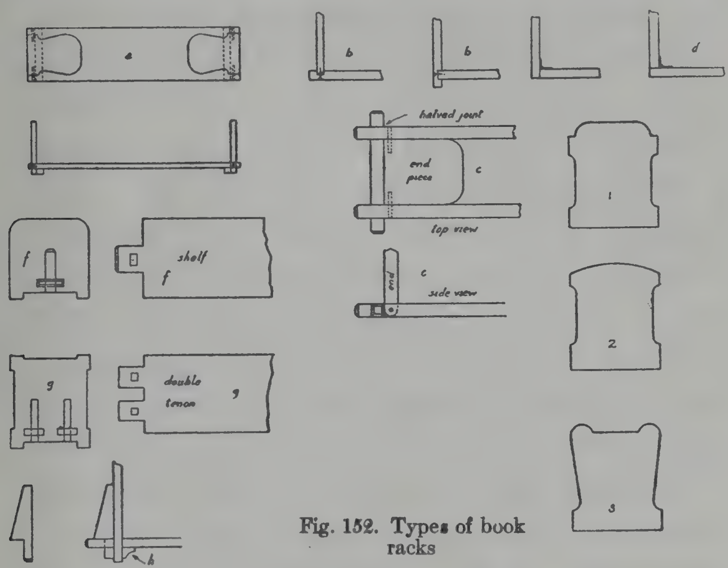


Fig. 152. Types of book racks

rack is shown in Fig. 152, at *a*. The ends are sawed out of the bottom piece, pivoted with two ¼-inch dowels and when stood upright the lower part strikes against a cleat, which acts as a rest for the rack and a stop for the end piece.

The weakness of most book racks lies in the gradual weakening of the ends at the joint so that the weight

of the books makes them lean outward. This should be considered carefully in working up the design. One of the weakest forms perhaps is shown at *b*. Theoretically, this is all right, but in practice the ends soon bend or lean out. A skeleton form, making use of the halved joint, is shown at *c*.

The two long sides and two short ends are squared up and halved as shown. All the ends are bevelled. Holes are bored for the pivots — ¼-inch dowels — a distance from the cross pieces equal to half the thickness of the folding ends. This is to insure the ends standing perfectly upright against cross pieces. If this distance is greater than half the thickness, the ends will lean out, and if less than half, the ends cannot be gotten in place. The bottom of the ends must be rounded, or they will not fold over.

The construction is very simple, and requires little material. Another very ordinary method is shown at *d*. It is as common and simple as it is weak and unsatisfactory. The ends are placed on the bottom piece and hinged. If a cheap and quick method is desired, it would be better to place the hinges as shown at *e*, because then the tendency to tilt out is prevented by the pressure against the bottom piece as long as the screws hold.

A far better method is to mortise the shelf through

the end pieces and fasten it with a good, healthy pin or wedge, as shown at *f;* and a still better plan is to have two mortises and two wedges, as shown at *g*.

In constructive design, nothing is lost by honesty. The ends in this case are held in place by pins, so instead of hiding the fact, emphasize it by making these pins big and strong enough to do their work. The rack may be further strengthened by adding corner brackets at *h*.

Having decided on the construction, the form of the ends may be taken up. This is affected somewhat by the construction, but some of the outlines tried by our boys and suggestive to other boys are shown at 1, 2, 3.

They used two distinct kinds. One was characterized by straight lines. These they decorated with chip carving. The other style was distinguished by curved outlines, and decorated by outlines made with the veining tool, and by staining the figures in various colours.

The stains they used were oil colours thinned with turpentine so as to bring out the grain of the wood, rather than to hide it, as in painting, and care was taken to tone down these colours to dull reds, browns, greens, and grays. For staining and polishing, turn to the last chapter.

XIX

THE USE OF THE GOUGE

"THERE is one tool you have not learned to use," said Ralph, one day, "and I think that it is about time you tried it."

"What tool is that?" asked Harry.

Fig. 155. The gouge

"The gouge ground or bevelled on the outside. (Fig. 155.)

"What is it used for?"

"For cutting concave curves, especially those below the surface. Suppose you practise on a piece of white wood."

A piece of white wood was squared up, a foot long and 1½ inches square. The lines shown in the figure were laid out with the pencil. The marking gauge is not suitable for this work, as it makes a sharp cut in the surface just where the edge is to come, so that after the gouge work is finished, it would show this edge split by the gauge mark. (Fig. 156.)

The two grooves from end to end were first cut,

removing a quarter circle, the curve being drawn on the ends by a pair of compasses or dividers. This gave excellent practice in freehand work, calling for good control over the hands, and a constant watching of the grain to prevent splitting.

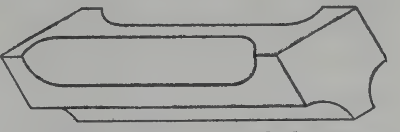


Fig. 156. Practise cuts with the gouge

The other two grooves or coves were next tried. Extra care had to be exercised here to prevent taking off the ends.

To give the boy further practice, the simple pen tray shown in Fig. 157 was sketched out, and the stock squared up.

The gouge work in this exercise was entirely be-

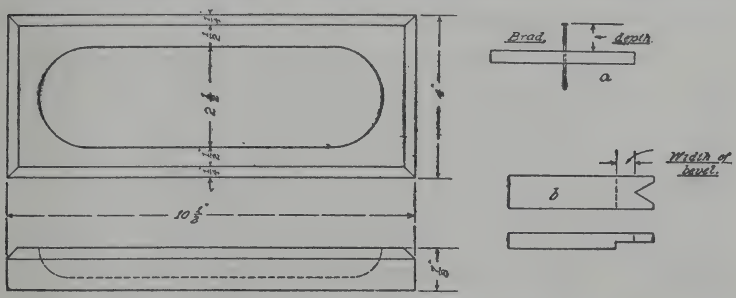


Fig. 157. An example of gouge work

neath the surface, and to make the tool work true to the drawing, a depth gauge was made as shown at *a*. This was simply a straight piece of waste

wood with a brad driven into it, carefully, until the head was the same distance above the surface as the depth of the groove called for in the drawing.

By inverting the gauge and running the brad head along the bottom of the groove, the depth could be gauged accurately. The wooden strip must rest on the surface at both sides of the groove, and the brad head just touches the bottom at the same time.

After the gouge work had been carried as far as possible, the groove was finished by sand-papering, first with No. 1½ and then with No. 0 sand-paper.

In laying out bevelled edges on a piece of this character, the same objection to the marking gauge holds as for gouged grooves. Ralph showed the boy a simple method of making a gauge for pencil lines to overcome this difficulty. He cut out a piece of white pine shaped as shown at *b*. The distance from the shoulder to the point of the V was equal to the width of the desired bevel or chamfer. The stock must be held in the vise, as both hands are required in the drawing of the lines. To make the width of the bevel greater, simply cut the shoulder further back with a knife, and to reduce the size, cut the V further in toward the shoulder.

This is a very convenient and inexpensive device, quickly made.

A more pretentious project was tried next (Fig. 158, *a*), which provides for a round ink bottle, and demands some nice chisel work. In the first pen tray the bevels had been all planed. On this second one, only three could be cut that way, as the one on the back had to be chiselled. The successive steps in the construction were as follows:

1. Square up stock.
2. Lay out the drawing on the wood.
3. Bore the hole for ink well half way through the wood with extension bit.
4. Smooth the bottom of the hole with chisel, holding it bevel down.
5. Gouge out the groove and gauge the depth.
6. Sand-paper the groove.
7. Cut out the outline of the back with the back saw and chisel.
8. Cut all the bevels, doing the back part — the most difficult—first.
9. Draw chip carving design.
10. Do the carving.
11. Rub down with wax dissolved in turpentine.
12. Insert ink well.

Design No. 3, shown at *b* (Fig. 158), called for

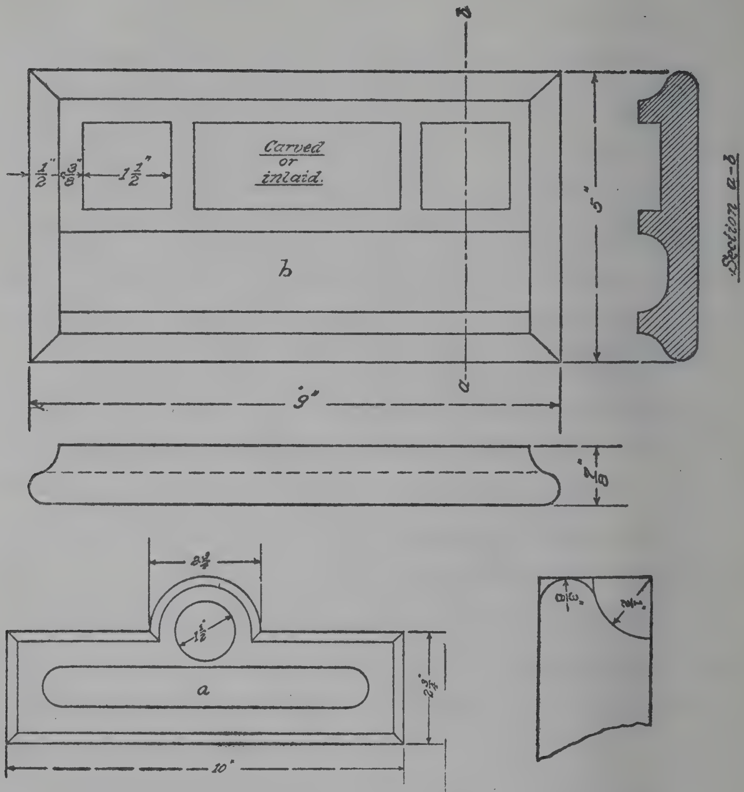


Fig. 158. Pen and ink trays

molded edges, places for two square ink wells, and a simple carved design in the flat space between them. The process in this case was as follows:

1. Square up.
2. Lay out the work from drawing.

3. Cut out squares ¼ inch deep with socket chisel and mallet.

4. Gouge groove.

5. Make moulded edges by first gouging the quarter circle shown in detail drawing, and doing the long sides with the grain first. Next remove the rest of the wood outside the curved outline with smoothing plane on long sides, block plane on ends. Sand-paper the groove and moulded edges.

6. Lay out and execute carving.

7. Rub down with wax or raw linseed oil.

8. Insert ink wells.

In place of carving this inkstand, an inlaid design could have been used, and the whole piece highly polished, but our boy had not yet had any practice in inlaying or polishing, so he used sweet gum wood and a chip carving design. Later on he made others out of black walnut and mahogany, and gave them a high polish. See the last chapter for polishing.

A very nice little problem in gouge work is shown in Fig. 159, a pen tray pure and simple, with no provision for ink wells.

The only new feature is the under cutting of the outside. The steps for this are:

1. Square up.

2. Lay out from a centre line, drawn completely around the block lengthwise, and draw with compasses and rule both top and bottom.

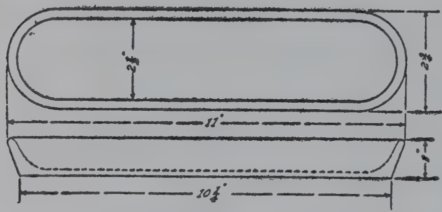


Fig. 159. The pen trap

3. Gouge groove.

4. Plane the long sides to outline of top and bottom lines.

5. Cut ends with back saw and chisel to semicircles on top and bottom.

6. Round upper edge with spokeshave, chisel and knife.

7. Sand-paper with coarse, followed by fine, sand-paper.

8. Polish or wax finish.

Perhaps the most severe test for gouge work is the pin tray shown at Fig. 160. This is something which could be made more cheaply and in less time from metal, but a skilful and careful boy can do it successfully in a hard wood, such as maple. The process is similar to the pen tray. The drawing is laid out on the squared stock, and the bowl cut out with the gouge.

The outside is best executed with a template, or better, two — one for the lengthwise section

and one for the width. A template is a form cut out of thin wood or metal; in this case ⅛-inch wood

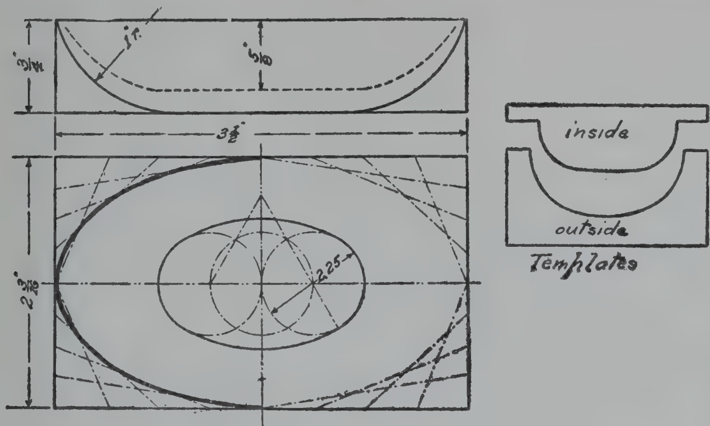


Fig. 160. The pin tray. A fine test of gouge work

should be used. By frequently holding these templates to the work, it may be quickly seen where the material is to be removed.

When the outside of the tray fits the templates, it is ready for sand-papering, and not before. To make the tray perfect, an inside template can be used. This template method is used in forming boat models.

XX

FOOTSTOOLS

THE making of household furniture is a fascinating employment, and as there are varying styles and fashions in nearly all things which pertain to our homes, it will always be an interesting study. The savage knows nothing of furniture, for the ground is his chair, bed, and table. As we go up in the scale of civilization, we find the characteristics of a people reflected in the details of their home life.

In Japan, the house and its equipment are characterized by directness, simplicity,and subtle beauty.

In America, we find a bewildering display of ever-changing devices, styles, forms, and schemes of decoration, in keeping with our rapidly changing and, we believe, rapidly improving taste in the intimate things of life.

This condition is reflected in our furniture as much as in our clothes and in the pictures we buy. The black walnut furniture, with its hard horsehair upholstering, has been followed by antique oak,

fumed oak, golden oak, forest green oak, mahogany, bird's-eye maple, French walnut, etc., and in a very few years we shall probably be using some of the beautiful but almost unknown woods of the Philippines, because fashions in woods are very materially affected by the lumber supply.

Gilt chairs — not made to sit on — have been followed by the more sensible mission style, bringing a much needed simplicity, directness, and strength, together with an unfortunate addition of weight for the housewife to move around when cleaning. There seems to be no great gain without some loss. Modern office furniture, with its simple and strong chairs, tables, and desks, can hardly be improved upon, and it is almost a pity that some of these excellencies cannot be introduced into the home, which is often overloaded, overdecorated, and encumbered with unnecessary articles.

Miss Louise Brigham gives us a fragrant breath of fresh air along this line in her interesting book on furniture made from boxes. What is needed is clear thinking. Never design nor make a piece of furniture without asking, "What is this to be used for? What will be required of it?" etc.

This is the gist of what Ralph said to Harry one day when they were about to launch out into the

making of footstools, tabourettes and other small pieces of furniture. Harry would have liked very much to start with a dining-room table, but Ralph suggested diplomatically that it might be a good scheme to try several smaller pieces first.

They decided on a footstool, and this is the catechism Ralph put Harry through as they worked out their drawing:

"What is a footstool for?"

"To rest your feet on."

"Is that all?"

"What else could it be used for?"

"Never answer a question by asking another! I should say that a footstool might have to stand hard usage. For instance, suppose you wanted to reach a shelf high up in a closet. If the stool was handy, you would probably stand on it. Others would do the same, and it is easily possible that somebody weighing over two hundred pounds might some day stand on it. So I should say, that the first requisite of a footstool was strength, and the second that it should not be easily upset.

"When designing furniture, just ask yourself such questions, and you will find that your designs will be affected by them. Now I believe that most footstools are too high and too easily upset."

The first design tried is shown in Fig. 173. The material used was ½-inch chestnut. After squaring up the top, the two grooves were cut to receive the upper ends of the legs. For grooves of this character, after cutting the lines as deep as possible

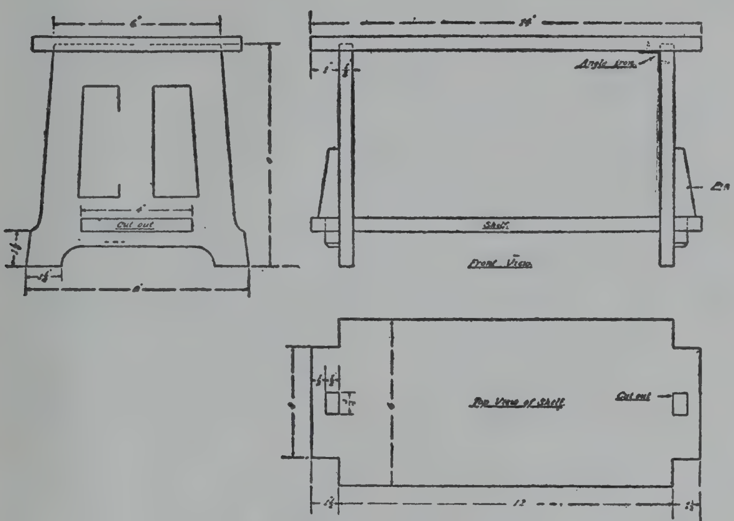


Fig. 173. First foot stool

with the knife, followed by the chisel, the router may be used. The cutter can be adjusted by means of the set screw, and a more uniform depth secured than with the chisel.

There was considerable work on the legs because of the mortise for the shelf, and the two openings above. These were cut out close to the line with

the turning saw after a hole had been bored in each space, as in scroll saw work.

The outline of the legs was obtained with the same tool, and finished with the gouge, spokeshave, and sand-paper. Where hard wood, such as oak, is used, the wood file may be applied to curved edges.

To overcome the tendency to spread, the legs were made rigid by cutting the tenons shown on the drawing of the shelf. In each tenon was cut the square hole for the wedges. This shelf, when securely wedged, bound the whole structure rigidly. When the question of securing the legs to the top came up, the boys were inclined to use round-head blue screws from the top, but after considering that they would be in end grain, it looked as if this would be the weakest part of the stool. The solution was an heroic one. Four angle irons were made out of strap iron taken from a packing case, and cut with a cold chisel into pieces 2½ inches long. Each had two holes drilled in it to receive the screws, and was then bent into shape in an iron vise. A monkey wrench can be used as a vise for work as light as this. The screws used were ⅜ inch long, one fastened in the top, the other in the leg, for each of the four angle irons.

Chestnut has a very open grain, and takes a

stain very well. Our boys bought a small can of paste filler, coloured it with burnt umber, thinned it with turpentine to the consistency of cream, and put it on with a brush. The surfaces were rubbed

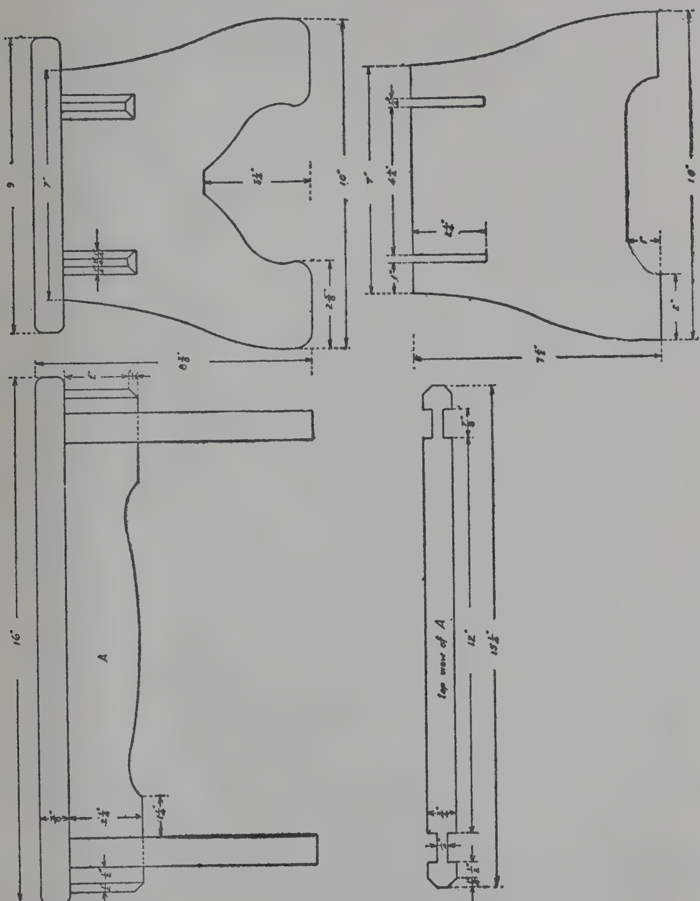
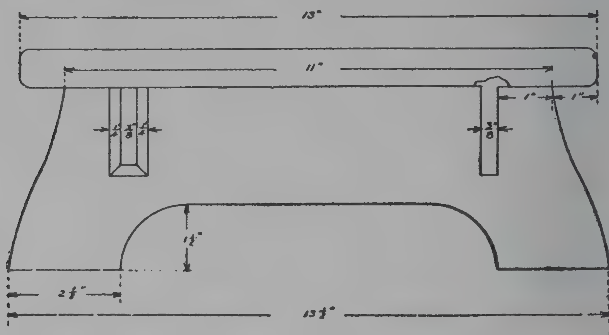


Fig. 174. Second design for footstool.

down with cotton waste, and then it was left over night, to be ready for polishing in the morning.

After this stool was finished, the boys looked it over critically, and decided that it could be improved



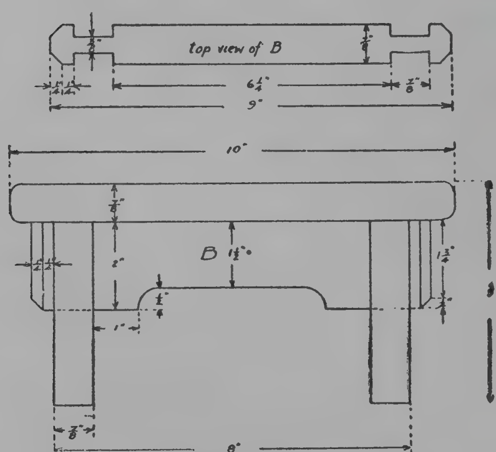


Fig. 175. Third footstool design

on, that it was too high and not heavy enough.

Footstool number two is shown in Fig. 174. In this design, the shelf is dispensed with, and two stretchers or side pieces substituted; stock ⅞ and ¾ inch thick took the place of ½ inch. The two ends were glued together with paper

between, cut out as one piece, afterward separated, and the paper and glue planed off. The curved outline was drawn on paper, traced on the wood, sawed

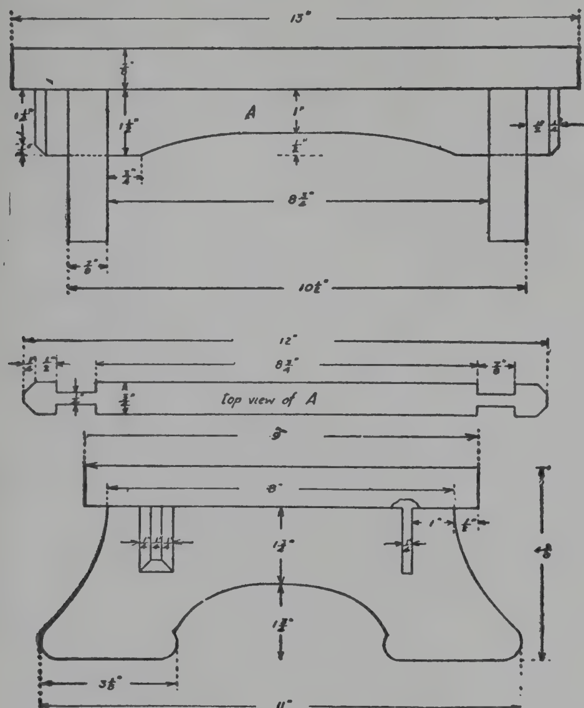


Fig. 176. Fourth footstool design

out with turning saw, and finished to line as in previous work.

The joint for fastening the side piece to the legs is shown in the drawing. It makes a strong and rigid combination, calling for a good fit. In putting

on the top piece, angle irons can be used, but the boys tried a new method. After gluing the joint, they bored holes and countersunk them through the sides, forcing flat-head screws 2¼ inches long up into the top.

Being below the level of the eye, these were invisible, and they saved the time and labour of making angle irons. Two screws on each side are enough to make a solid piece of work. The material was quartered oak with antique finish. To produce this effect, lampblack dissolved in turpentine was added to the filler, and after drying was polished to a dead flat finish. (See polishing chapter.)

Design number three is shown in Fig. 175. The legs run the long way of the stool; joints the same as number two; top fastened by screws through cross piece. The height, being much less than in the first designs, gives it a very massive and substantial appearance. All eight edges of the top have been slightly rounded with plane and sand-paper. This stool is non-upsetable in the direction of its length. Stand on the extreme end of the top and lean backward; the stool will not tilt up in the slightest degree. Harry tried this several times, but it remained on the floor with all four feet. This does not apply to the width, so the boys designed number four

(Fig. 176), which would not upset from the side, where the feet are usually placed. It is even lower than number three, and as the other dimensions are practically the same, it appears even more massive.

The construction is similar to number three, but the legs are again at the ends, and the whole being made of oak, or ash, it is practically indestructible.

A very beautiful golden-brown finish may be given these stools by first coating them with bichromate of potash.

This chemical comes in crystals, which readily dissolve in water. Put it on with a one-inch varnish brush and, when dry, sand-paper down flat with No. 0 sand-paper. Two or three coats of shellac, each allowed to harden and dry thoroughly before being rubbed down with sand-paper, will give a satisfactory polish. Finish by a rub down with raw linseed oil, and wipe dry.

XXI

THE TABOURETTE

THIS is a favourite problem in woodwork for boys, because the tabourette can be put to many uses. It may hold books or magazines, serve as a pedestal for a jardinière, for vases of flowers, for smokers' sets, etc. Its forms are many, and the methods of finishing and decorating infinite.

The five styles shown in Figs. 177 and 178 are perhaps the most common ones, and they are arranged according to the difficulty of construction.

No. 1. Has a circular top supported by square legs, bound to a lower shelf.

No 2. Has an octagonal top supported by flat legs, which are held together by two strips halved together at the centre, and mortised through the legs. It is stronger than No. 1.

No 3. Is the familiar hexagonal form, with only three legs, made rigid by fastening to an hexagonal shelf.

No. 4. Is the standard square form in mission style, mortised together.

No 5. One of the simplest in appearance, is the most difficult to construct, because of the six long joints mitred at 120 degrees, the well-known Moorish style.

As it is easily possible for any boy to make any of these tabourettes with ordinary tools and ordinary patience, they will be taken up in detail.

TABOURETTE NUMBER ONE

Stock.—Four pieces for the legs, 1½ inches square.

The height varies, usually being between fourteen and eighteen inches. It is purely a matter of proportion. Sixteen has been adopted in the drawing as a good average. The top, a circle thirteen inches in diameter, is cut from a piece thirteen inches square and ⅞ inch thick. The shelf may be an exact duplicate of the top, but it appears much better, as shown in the drawing, as a square with corners cut off to fit against the legs. The method of getting this form is shown by dotted lines on the circular top.

The method of construction is very simple. The top piece being laid out, is cut close to the line with turning saw, and finished to line with chisel and spokeshave. The square openings for legs are sawed out and the wood removed with a chisel.

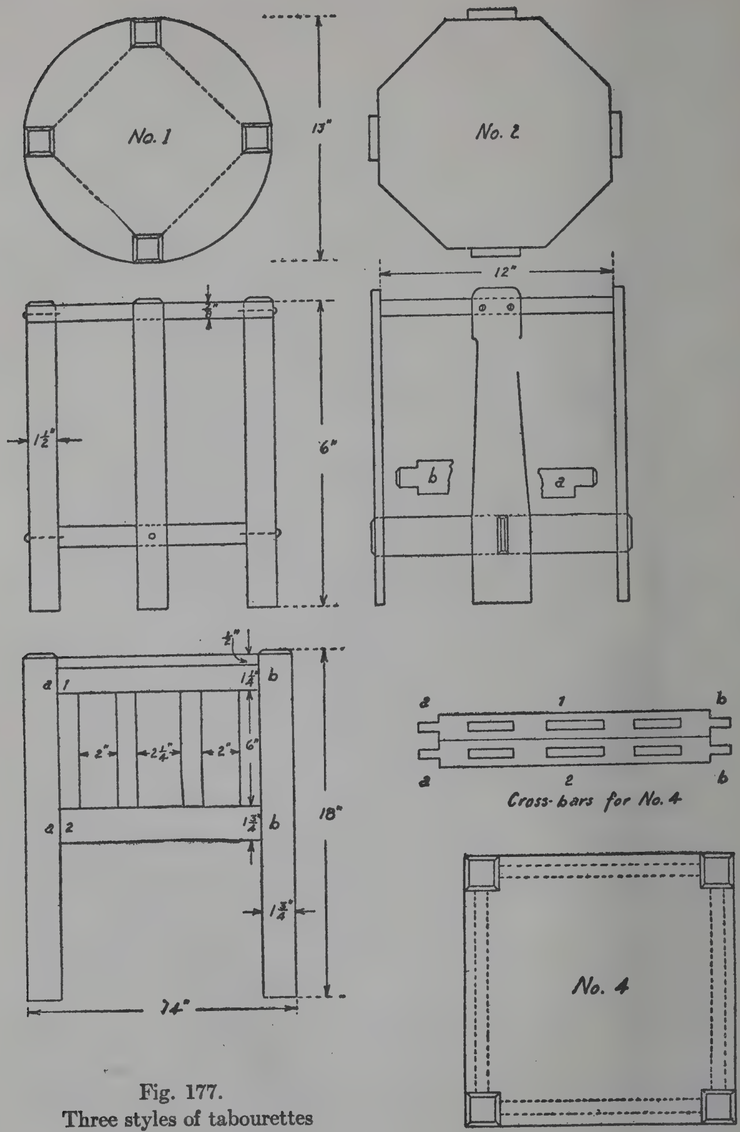


Fig. 177.
Three styles of tabourettes

All chisel work should be done on a bench hook or on a piece of scrap board, as a cutting block.

In preparing to assemble, lay the four legs side by side on the bench top or fasten in the vise. Make sure they are equal in length. Four and a half inches from one end draw a pencil line with try square across all four. Half an inch from the other end draw a similar line; this end is to be the top. These pencil lines are for locating the holes for the screws, so that they will all be on the same level. Bore a hole on each line with a bit or drill, large enough so that the body of a round-head blue screw either $2\frac{1}{4}$ or $2\frac{1}{2}$ inches long will just slide through.

Before assembling, bevel or round the top of each leg about $\frac{1}{8}$ inch. Fasten the four legs to the top with the screws, slip the shelf into position, and make fast in the same manner. Stand the tabourette on a level surface, and if it needs levelling, proceed as explained in the making of saw horse.

TABOURETTE NUMBER TWO

Tabourette number two may be modified by designing legs with slight curves. Before cutting these, lay out the four mortises just as the centres for screw holes were located in previous model so that all four will be equally distant from the floor. Cut out mortises by boring several holes within

the space to be cut and finish to line with chisel. These mortises should be laid out on both sides of the leg by squaring lines around the four sides.

The top needs no description, as it is just a plain octagon. The principal work in this model is on the cross pieces. They should be laid out carefully, side by side, to make sure that the distance across from shoulder to shoulder is exactly alike on both. The tenon may have two shoulders, as shown at *b*, or only one, as at *a*, but in either case the mortises cut in the legs must exactly fit the tenon. The halved joint in the centre must also be carefully fitted.

When all the parts are ready to assemble, drill two holes near the top of each leg for the round-head screws. Insert all the tenons into their mortises and fasten the legs to the top. A little glue may be used in the mortise and tenon joints and one brad should then be driven from the side or edge of each leg through the tenon. Sink the brad below the surface with nail set.

TABOURETTE NUMBER THREE

This is simple enough except for laying out the hexagon. This form will appear crude unless the legs are modified, and two or three suggestions for this are shown.

The construction consists in fastening to the under side of the top piece a hexagon of $\frac{7}{8}$-inch pine eight inches in diameter, making sides four inches long. Every alternate side of this under piece should be made with a sloping edge to conform to the slant of the legs, of which there are only three. Drill or bore four holes in each leg, two $\frac{7}{16}$ inch from the upper edge, and two to hold the hexagonal shelf. The top edge of the legs should be bevelled with a block plane to fit snugly against the under side of the top. Three sides of the shelf — every alternate one — should be bevelled in the same way to fit against the inside of the legs.

When ready to assemble, fasten pine hexagon to the under side of the top with six $1\frac{1}{4}$-inch screws.

Attach the legs to the three sloping edges of this under hexagon lightly with round-head screws. Leave the screw heads projecting about $\frac{1}{4}$ inch until the shelf has been fastened in position, then drive them home with the screw-driver. This is one of the simplest of tabourettes to make, but it is open to criticism. The sloping legs give it a wide base so that it is less easily upset than the other forms; but the pressure from above tends to spread them and pull the structure apart. This tendency must be counteracted by a tie piece, which in this

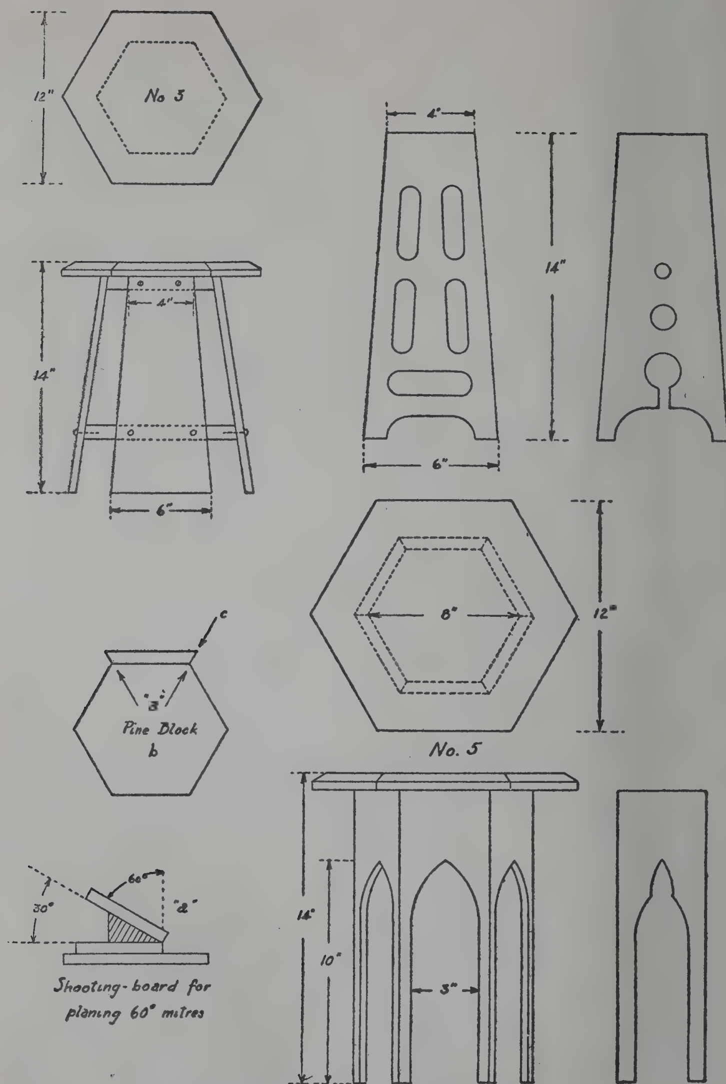


Fig. 178. Two styles of tabourettes

case is only a shelf held by screws, some of which are in end grain.

Of course any form may be criticised. The most beautiful of all, the Turkish or Moorish, on account of its overhanging top and small base, is the most easily upset, and in designing new forms all these points must be considered.

TABOURETTE NUMBER FOUR

This is an ideal example of the mission type taken from Mr. Fred D. Cranshaw's book, "Problems in Furniture Making." It calls for forty mortise and tenon joints, and as it is usually made in oak, it requires considerable time for laying out as well as for cutting.

Twenty-four of these joints can be dispensed with by panelling the sides in place of the lattice work. By hinging the top and putting in a bottom, the tabourette becomes a ladies' work box, a shoe box, etc.

In a project of this kind it is absolutely necessary to work systematically. Letter or number each part. Mark the legs *a b c d*, and proceed to work in pairs. After squaring up all the pieces, take side *a b*. Lay out the four joints on *a* and *b* which are to face each other, finish these ready for assembling, lay aside

a, and lay out *b c*, etc. When you have finished all four sides around to the starting point, stand the four legs up in the position they are to occupy and check up the work to see if any mistake has been made. Treat the cross bars in the same way, marking the tenons *a*1, *a*2, *b*1, *b*2, etc. When you have gotten around the second time, assemble the whole thing and look again for errors.

Take apart and lay out mortises in cross pieces by pairs. Fasten 1 and 2 together in the vise with the edges which are to face each other up as shown in Fig. 177.

Square the lines across both pieces, remove from vise and gauge the horizontal edges of mortises with marking gauge.

To avoid confusion and for change of work, cut out these mortises before laying out the next set, and so for the third time work around to the starting point.

A fourth trip around, making and fitting the upright slats, and the tabourette is ready to assemble. By using liquid glue, which hardens slowly, the whole structure can be put together, fastened with large hand screws or clamps, and left over night to dry.

While the glue is setting, measure carefully for the top, to see if there is any variation from dimen-

sions on drawing, and cut out the top piece. By this time, the amateur woodworker will have more respect for the mission style than ever, and will appreciate the difficulty of reaching simplicity.

The best method of securing the top is with small angle irons fastened to it and cross pieces on the inside. Invert the tabourette, after screwing the angles to the cross pieces, and with the top on the floor, drive home the last four screws.

No; it is not finished! There remains the polishing. See the last chapter.

TABOURETTE NUMBER FIVE

This is so radically different in construction from the previous forms that it requires special consideration. Twelve edges must be planed to a 60-degree mitre throughout their entire length and the fit must be perfect. To accomplish this, first cut out two hexagons from ½-inch pine, 8 inches in diameter, and exactly alike. Construct a special shooting board, at least three inches longer than the legs. Plane a strip of white pine to the shape of a wedge whose angle is 30 degrees. Nail it to the top of shooting board, as shown in Fig. 178 at *a*. By laying the piece to be mitred on this, the edge can be planed to 60 degrees. Lay this on the two

pine hexagons as shown at *b*, and with the knife make a mark at the angle *a* on both ends. Connect these two points by a sharp line drawn with a straight edge. Plane this edge on the shooting board to point *a*, giving angle *a c*. Tack this leg by brads to the two hexagons, at each extreme end, driving brads only partly in, so that they can be easily withdrawn. Fit the second leg to the first, and so on around to the starting point. Number or letter the legs, and the corresponding faces of the hexagons, so that they may be easily replaced.

Next take off the legs, lay out and cut the openings with the usual tools. These may be plain Gothic arches or simple modifications.

When the legs are finished, make the hexagonal top and prepare to assemble. Use the best glue. Fasten the first leg in its original position on the pine hexagons, using 1¼-inch brads at the top, driving them all the way into the original holes. Put a coating of glue on one edge throughout its whole length, and rub the next leg up close into position. The brads in the lower hexagon must be driven in only part way, as they are to be removed again. Put all six legs into position in this manner. To bind the legs together while the glue is drying, heavy cord should be wound around them, using

strips of wood to prevent marring the angles. Let the whole stand over night.

Next day, plane off any glue that may show, removing the two brads at the bottom, dressing down one side at a time until you have reached the last leg. The pine hexagon at the bottom may be taken out, if it doesn't fall out. Sand-paper the sides with No. 0 sand-paper, wrapped around a block.

The top only remains to be adjusted.

Drill six holes in the pine hexagon at the top, and pass six $\frac{3}{4}$ or $\frac{7}{8}$ inch screws through from the under side into the top piece by inverting, with top on the floor.

There is so much careful work on this tabourette that it is worthy of good material. Mahogany is very suitable, the light coloured bay wood being the cheapest variety; but of course other woods will do. In case bay wood is used, it can be given the appearance of old mahogany by first coating it with a wash of potassium bichromate. Polish.

XXII

THE DOVETAIL JOINT

WHILE most mission furniture is put together with the mortise and tenon joint, cabinet work calls for the dovetail. All the skill and accuracy possible are needed in dovetailing, and when well put together with this style of joinery, a piece of furniture should last indefinitely.

The making of joints just for practice may not be very interesting, but in the case of the dovetail it is decidedly advisable. This is what Ralph decided in Harry's case, and he was required to make first a single open joint as shown in Fig. 179. The piece marked *a* was laid out first, after squaring up the stock, and the shaded portion removed with back saw and chisel, sawing so close to the oblique lines that no chiselling was required on these two sides. Piece *b* was next fastened upright in the

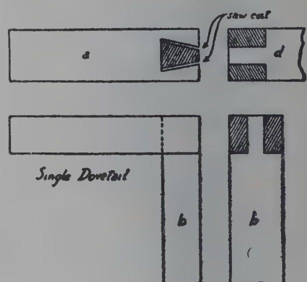


Fig. 179

vise, piece *a* being laid over *b* in a horizontal position, and the form of the dovetail scribed with a knife point. In other words, the first piece cut out was used as a template for laying out the second. The form of the dovetail appeared in knife lines on the end of piece *b*. The laying out of *b* was then completed as shown at *d*. The darkened portions were removed with back saw and chisel, and the two parts carefully fitted and glued together.

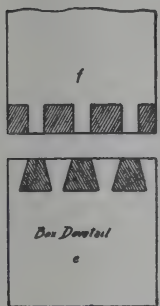


Fig. 180

This method of laying out dovetails is much surer than that of laying out each piece separately according to the dimensions, as any variation from the figures is duplicated on the second piece, so that they must fit.

This single dovetail was followed by a box dovetail joint comprising three dovetails on one piece, as shown in Fig. 180. The method was the same as before, the three spaces being laid out, sawed, and chiselled. After testing to see that the bottoms of the cuts were square, piece *f* was laid out, cut, and fitted. Seven-eighths pine is good for this practice work, but white wood gives better practice, in that it is harder, and the dovetails cannot be forced together without breaking, unless the fit is good. The harder the stock used, of course the more true this is.

After successfully making these two practice joints, the boy was ready to try his skill at cabinet work. He began with a toilet box in black walnut, to be inlaid later and polished. The over-all dimensions were 11 x 7 x 3½ inches, the height, exclusive of top and bottom pieces, being three inches.

The bill of material read:

2 pcs. walnut 11 x 3 x ½
2 pcs. walnut 7 x 3 x ½
2 pcs. walnut 11 x 7 x ½

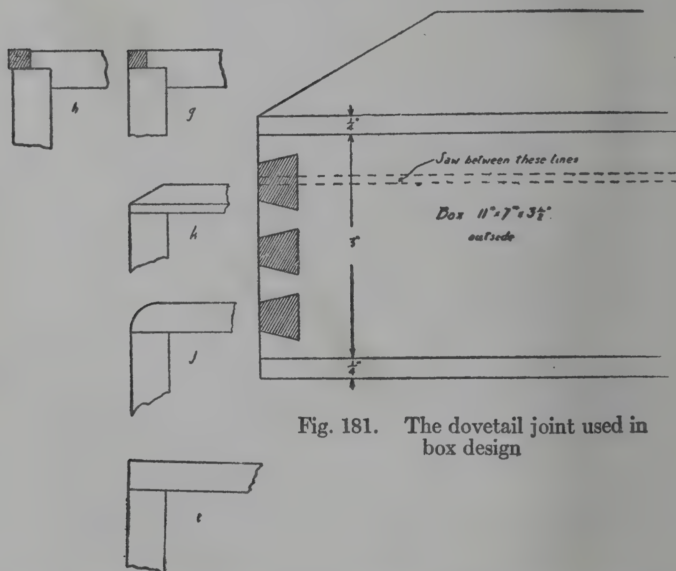


Fig. 181. The dovetail joint used in box design

The process was as follows: Sides squared up and tested. Ends squared up and tested. Sides and ends compared to see if all were exactly the

same height. Dovetail joints laid out on side pieces. (The two sides can be glued together with paper between, and cut at the same time, but on this first box the boys laid out each side separately.)

Joints cut and chiselled to line and lettered *a b c d*. This was to avoid confusion in laying out the ends from the sides. Ends laid out from sides with knife. Ends cut and fitted to sides. This short description meant the fitting of four box dovetails, or twelve individual dovetail joints, and it took considerable time. The four pieces were glued and fastened in hand screws over night. Particular care was taken to see that the pressure was evenly distributed, so as not to throw the box out of square.

While the glue was hardening, the top and bottom were squared up half an inch shorter and half an inch narrower than the finished box was to be.

A quarter-inch rabbet was cut on the four edges of both top and bottom. When the box was taken out of the hand screws next day the rabbet allowed top and bottom to fit sides and ends as shown in *g* (Fig. 181). They were glued into position, and again placed in hand screws.

This construction left a quarter-inch rabbet all around the top and bottom of the box. This

space was to be filled with square pieces of white holly as an ornamental feature. While the glue was hardening a second time, these little square strips were prepared. The boys found that it would not be necessary to square up the four sides, for if one corner were made perfectly square, the other sides could be planed off after the strips were glued on.

When the hand screws were removed again, all traces of glue in the rabbet were carefully taken off with a sharp chisel. The strips of holly were sawed in the mitre box, and fitted around the four sides of top and bottom. The construction at this stage is shown at *h*, with the holly strips projecting beyond the walnut sides, ends and top.

The strips were fitted and glued in position, and then held in place during the drying process by winding the box in all directions with stout twine.

When thoroughly hard and dry, the whole thing was squared up, as if it were a solid block, and scraped with a steel scraper.

Gauge lines were then made for the cover, as described in the chapter on toilet boxes, sawed, fitted, hinged, and polished.

The method of ornamenting the edges by strips of different coloured woods may be omitted, and the work considerably simplified by gluing the top and bottom on, as shown in Fig. 181 at *i*, and if this seems too crude, a bevel ¼ inch on the sides and ends and ½ inch on the top can be made with the plane. Still another method is to round the edges as shown at *j*.

Where the top is to be inlaid, either *j* or *k* is preferable, as ornamented corners combined with a decorated top is rather too much ornamentation for good taste.

XXIII

TOOL CASES AND CHESTS

AFTER our boys had made several of these dovetailed boxes, Ralph announced that his pupil was ready to attack the construction of a tool cabinet. It was to be fastened to the wall over the bench, designed to hold most of the small tools, and to be in such a position that it could be reached from the front of the bench.

The cabinet designed was really a dovetailed box 30 x 20 x 6 inches over all. It was made of ½-inch quartered oak except the back, which was ½-inch pine. The bill of material was:

1 piece pine 30 x 20 x ½	2 pieces oak 20 x 5 ½
1 piece oak 30 x 20 x ½	2 pieces oak 30 x 5 ½

The front and back, each 30 x 20 inches, were made of two pieces 30 x 10 inches, jointed and glued, placed in clamps over night and the joints planed down to take off the excess glue which had oozed out under pressure of the clamps. While these two parts were gluing, the sides and ends were dovetailed as in previous boxes.

When the front and back pieces were glued in place on the box, they were further fastened by 1-inch brads, set below the surface, and the holes filled with putty, coloured to correspond with

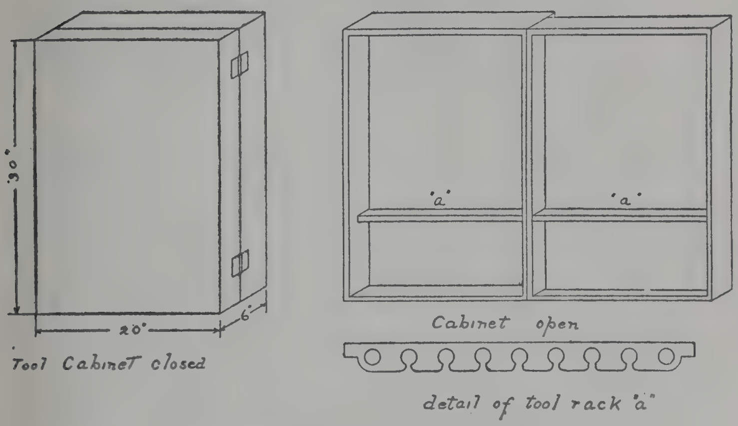


Fig. 189. A tool cabinet

the stain. The colour of the finish was a dark, handsome green. The box was sawed in two along a line $2\frac{1}{2}$ inches from the front.

This divided the cabinet into two parts, the door or front section having a clear depth of 2 inches, and the back or wall section a depth of 3 inches.

After hinging the door section in position, the cabinet was stained inside and out, the outside polished and a hook for fastening the door shut was placed in position.

The cabinet was fastened to the studding of the shop by four strong screws $1\frac{1}{2}$ inches long. The various nails, hooks, and tool racks were next added and the cabinet was ready to use.

Patent racks for holding chisels, gouges, etc., are sold in hardware stores, but our boys preferred to make their own. Their chisel rack is shown in Fig. 189.

After squaring up and cutting out the recesses at the ends, holes were bored, the opening from the front cut with back saw, and the sharp edges rounded with chisel and sand-paper.

Holes for the screws at the ends were bored and countersunk.

In locating a tool cabinet of this kind, while it should be very easily reached, and is usually open during work hours, it should be placed high enough so as to be easily opened or closed without striking tools and work on the bench. In other words, it should not be necessary to clear the bench top in order to open the cabinet. About 6 inches between under side of tool cabinet and bench top is about right.

An old-fashioned tool chest, suitable for shipping a whole kit of tools any distance, is shown in Fig. 190. These chests were usually fitted with trays

divided into compartments for small tools and hardware. Such a chest may be made of either hard or soft wood and its construction is as follows:

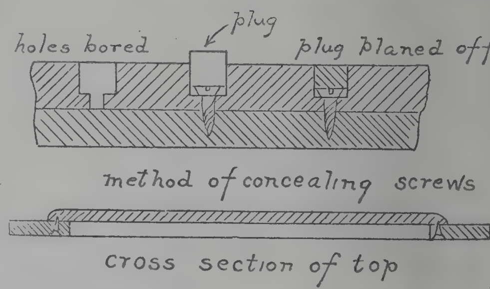
After making out a list of material, square up sides and ends exactly as in making any box. Lay out, cut and fit the dovetails. The bottom, on account of its width, will have to be made of two pieces. These may be jointed, glued and placed in clamps or put together with a tongue and groove joint. The latter plan calls for a special plane. Having prepared the bottom by either of these methods, bore and countersink holes about 6 inches apart in the bottom and secure rigidly to sides and ends by 1½ or 1¾ inch flat-head screws.

For the top, make a frame from ⅝ to ¾ inch thick and 3 or 4 inches wide, putting the ends together with end lap or mortise and tenon joints.

Secure this frame to top of box by screws. These may be round-heads, or if it is desirable to hide them, the method shown in Fig. 190 can be used. This is accomplished by boring a 3/16-inch hole through the top frame. At the same centre a ½-inch hole is bored partly through. The screw is driven home and a round wooden plug glued into the ½-inch hole. When dry, this plug is sawed off and planed smooth.

The top frame having been secured, two gauge lines are made for sawing the cover, as in previous boxes, and the two parts dressed to gauge lines, ready for hinging.

Before putting on the hinges, the top is to be finished with a raised panel. Square up a piece of stock two inches longer and wider than the open space in the top frame. Round upper edges, and secure to frame by flat-head screws from the under side through holes bored and countersunk.



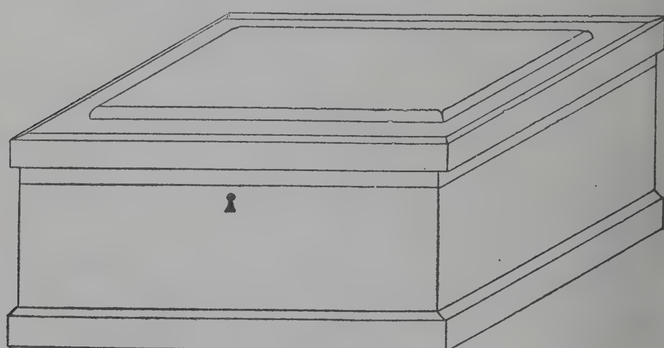


Fig. 190. The old-fashioned tool chest

Next put on hinges, which should be large and

strong, the variety known as strap hinges. Cut out space for lock, and fit. The holes for key are bored with a gimlet bit and cut out enough to allow

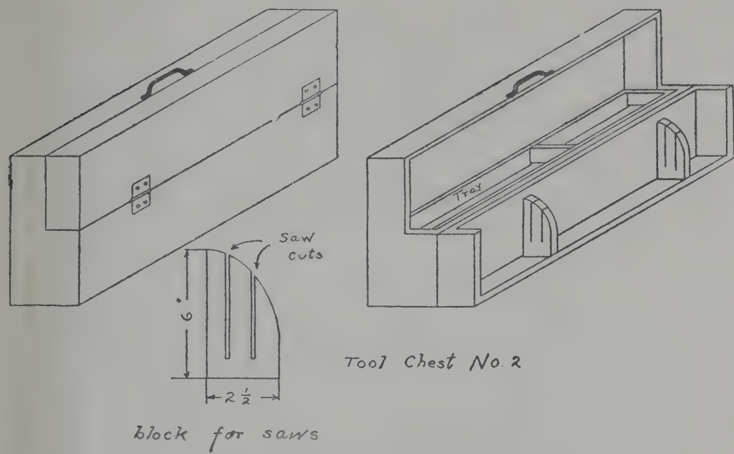


Fig. 191. Suit case tool chest

the key to enter freely; or hasp, staple and padlock may be used.

The bevelled base is mitred at corners, and brass corner plates to protect these lower corners are added.

The strip at the top corresponding to the base may be mitred and protected with corner plates, or the ordinary butt joint can be used. The bevel on this strip may be omitted. A chest of this variety, made of pine and painted, will stand a great deal of rough usage. Iron or brass handles at the

ends are recommended for convenience in carrying. Our boys were not satisfied with this form of tool chest, as it required two people to carry it, and after some experimenting they evolved one in the form of a dress suit case, long, narrow, and high, that could be easily carried. It is shown in Fig. 191.

They first made a solid box 30 x 15 x 7 inches over all. It was put together with butt joints securely nailed, using ½-inch white wood.

One quarter of the box was sawed out, as shown on the end view, and hinged to the body by ornamental brass hinges. This quarter was fitted for two saws by making two blocks as shown in the drawing. The rip and cross cut saws were fitted into the saw kerfs cut in these two blocks, placed securely in the cover, and were held in place by a small piece of leather strap taken from a school book strap and nailed to inside of cover. A tray for small tools was made of ¼-inch stock the full length and width of the inside of the chest 1½ inches deep and made to rest flush with the top of lower section on little corner strips glued in the four corners.

For handle, two pieces of leather strap were secured, one to each top section, by screws. When

the box was closed, these two straps came together and made a good handle. The objection to a solid handle is that it must be entirely on one section and that takes it out of the centre, so that the weight is not evenly distributed.

This is one of the most satisfactory styles of tool carrier devised. It will hold practically the whole kit and may be picked up like a dress suit case and transported just as readily. A hook and eye or hasp, staple and padlock should be used to hold the case securely closed.

For carrying bits of various kinds and sizes, a roll of ticking or denim divided into separate spaces is very desirable. These rolls with straps are sold in tool houses, but may be made at home by the sewing department. Besides protecting the cutting edges, they help to keep out dampness and rust.

XXIV

BOOKCASES AND MAGAZINE RACKS

THE WALL RACK

IN THE modern home, the orderly arrangement of books and magazines calls for ample shelf space and the book shelf becomes a favourite piece of furniture among amateur woodworkers. The book rack for the books of the day has been taken up in a previous chapter. The book shelf for hanging on the wall is blocked out in Fig. 192.

The questions to be considered in the design are:

No. 1. Methods of fastening shelves to ends.

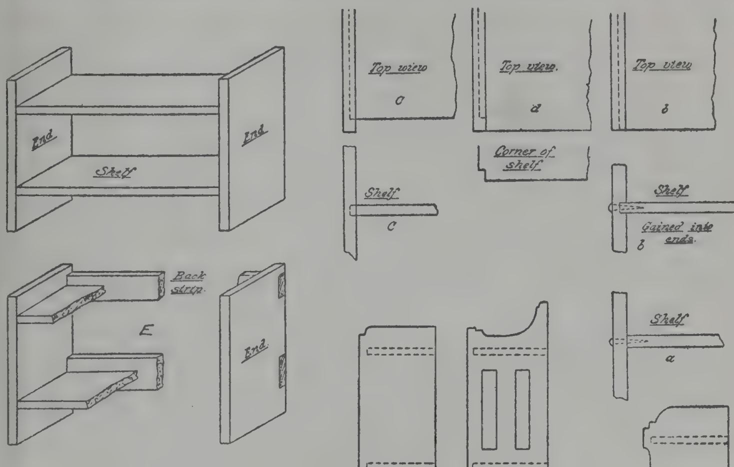
No. 2. The design of the ends.

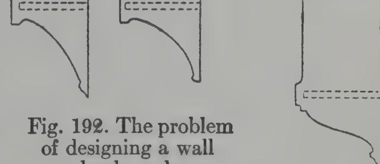
No. 3. The back: is it necessary, and if so shall it be solid? Outline of back.

No. 4. Method of fastening to wall.

No. 1. The method of bringing shelves and ends together with plain butt joint and fastening with a round-head screw from the outside is the easiest and poorest. The whole weight on the shelves is carried by the screws. This method is shown at *a*. At *b*, a better method is indicated, the shelf being

gained into the end and held in position by the screws. The weight in this case is carried by the ends. To hide the joint, the shelf may be slightly narrower than the end piece as shown in the top





view at *c*, or the two parts may be of the same width as at *d*, the gained joint stopping half an inch or so short of the full width. These details apply to bookcases that stand on the floor as well as to smaller ones.

Fig. 192. The problem of designing a wall book rack

No. 2. The design of the ends is largely a matter of artistic taste, and where curves are used, the lower part is usually formed in such a way as to suggest a bracket.

No. 3. A back is only necessary to give the rack rigidity and to protect the wall. If made solid — *i. e.*, to cover the whole space between ends — it uses a good deal of wood and adds considerable weight. *E* shows a method of using only top and bottom strips. They will make the rack sufficiently rigid and the strip should be gained into the ends, bringing them flush with the back of end pieces.

No. 4. Find the location of wall studs by dropping a line with weight on it (plumb) from the nails on picture moulding, or by bringing the weight in front of nails on base board. Make fine pencil marks on the wall where the studs have been located. Find the horizontal distance between the marks and at this distance drill holes in back of book rack and secure to the studs by screws. This brings all the strain on the back strips. If the rack has no back, square up two hard wood strips about 3/4 inch square and as long as the shelves. Drill screw holes in these strips and fasten to studs. Drill vertical holes at the back of each shelf 3/8 inch in from edge, fit the shelves over cleats and screw down into them from upper side of shelves.

The cleats should be finished in the same colour as the book rack. This method makes a very solid and permanent fastening.

The length of a wall rack should be limited ordinarily to three feet, as the weight of three feet of books will give considerable sag to the shelves, and a greater length will call for a vertical partition and corresponding bracket underneath for its support.

THE BOOKCASE

This piece of furniture is seen in so many forms that a volume would be necessary simply to catalogue them. The essential features are strong ends or sides, usually a solid back, a base, shelves, often adjustable as to spacing, a top more or less ornamental, and often glass doors.

Perhaps the most important point in the construction is strength. A wobbly bookcase is an abomination, and the weight to be carried is frequently enormous.

A typical case without doors will be taken up and this may be modified, used as a unit and doubled or trebled at the will of the young carpenter. (Fig. 193.)

If it is made to occupy a certain space in a permanent home, it may be built in and made solid with the wall, but this is not often desirable, particularly in America, where people move frequently. As a general rule, two small bookcases are better than one large one. They may be easily shifted,

changed from room to room, and are more apt to fit between windows.

The uprights 4 feet 4 inches long, 8 inches wide and ⅞ inch thick, are rabbeted at the back so that the joint will not show from the side. The back is to be of ½-inch white wood stained the same colour as the sides. The under top piece and bottom are gained

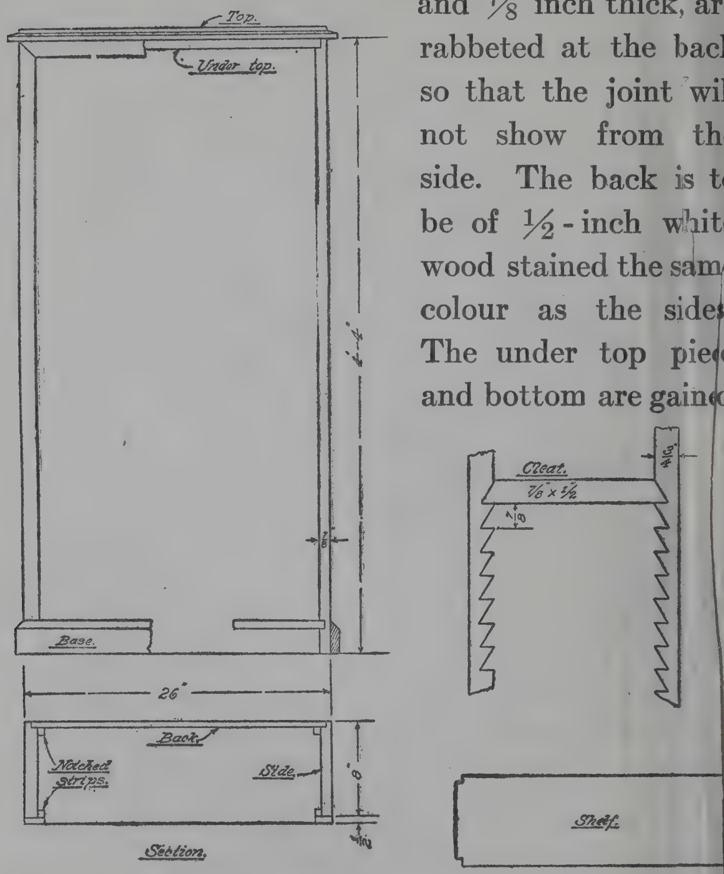


Fig. 193. The bookcase

into the sides, both joints being hidden b

the later construction. The 3-inch bevelled base is mitred at the corners and cut off square at the back, covering only three sides, as the back is to be flush from top to bottom. The top is to have a moulded edge on three sides, and to be fastened to under top piece by flat-head screws from the under side through countersunk holes.

The four solid shelves are made adjustable in their spacing by the old-fashioned method of saw-toothed strips in each corner. Strips $\frac{7}{8}$ x $\frac{1}{2}$ inch are made to fit in the toothed spaces, and the shelves rest on these strips, of which two must be provided for each shelf.

The four toothed strips should be laid out and cut together to insure the shelves being level. The dimensions for all these pieces are given in the detailed drawings.

The front edges are covered by $\frac{1}{2}$-inch strips, beaded if desired, mitred at the top and cut to fit the bevelled base below. Nailed on with brads, these are set and the holes filled with putty, coloured to match the finish.

In the mission style, the shelves are frequently mortised through the sides and secured by pins or wedges. In this type of bookcase, a solid back is rarely used, and base and top are omitted. In

a design of this kind, the top shelf becomes a book rack with ornamental ends. Often only the upper and lower shelves are mortised, the others being gained into the sides as described under wall racks. The lower part of the side is frequently modified to give a wider base and to make the case more stable. One objection to this is the amount of material wasted in cutting out, as the stock for the sides must be the full width of the base.

XXV

MISSION FURNITURE

THE library table (Fig. 196) is a good example of solid and permanent furniture construction. It represents the main principles of : mission style — solidity, strength, simplicity, aight lines, mortise and tenon joints, etc.

[o a boy who has worked carefully up to this nt it is entirely possible.

.s the top is the only part to be glued up, should be done first. Three boards ⅞-inch quartered oak 10 inches wide, or an valent that will aggregate a trifle over 30 es, and 4 feet long, should be jointed and ared for dowelling. The method of doing this own at *a*, where two jointed pieces are clamped ther. The distance between dowels lengthwise sd be measured, and lines squared across the e with knife and try square. Two pencil lines, a *b*, should be made across the joint. Set tharking gauge at 7/16 inch. Remove the b from vise or clamp, and from the faces

touched by pencil lines, gauge lines cutting across the three knife lines on each edge.

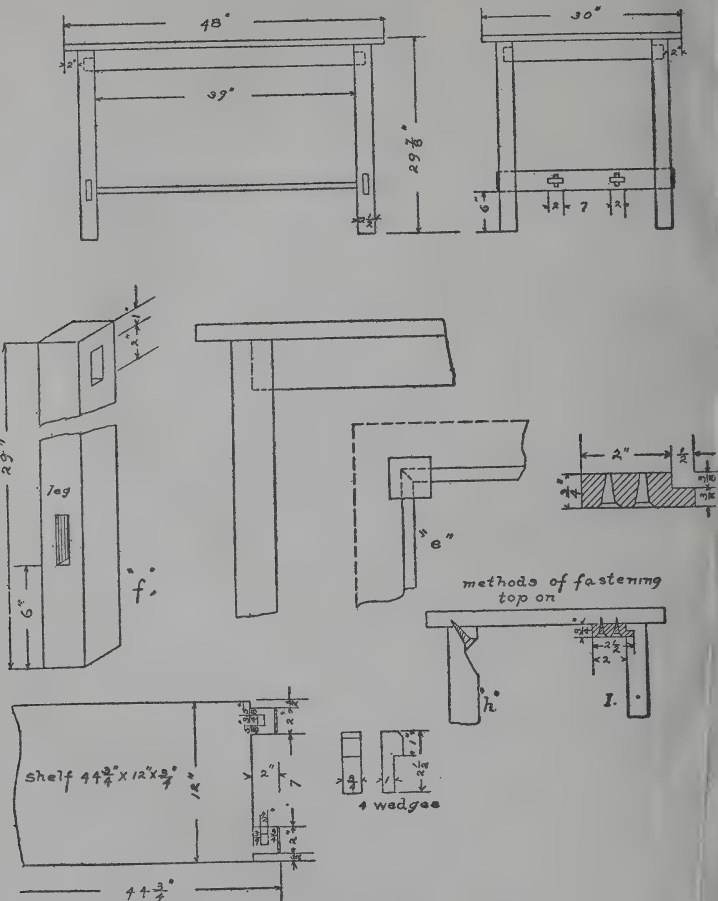


Fig. 196. A mission library table

Where these lines cross, bore ⅜-inch holes with a dowel bit to the depth of at least 1 inch. Lay out

the other dowelled joint in the same manner. Saw six pieces of 3/8-inch dowel 2 inches long, and glue ends of each dowel in the holes prepared in the middle board, as shown at *c*.

Put a thin layer of glue on the joints with a brush and clamp the three pieces together. While the glue is hardening, proceed with the frame. This consists of four legs, four top rails, the lower cross rails, a shelf, and four wedges.

The sizes are as follows:

Top rails	2	42 x 3 x 7/8
Top rails	2	24 x 3 x 7/8
Cross rails	2	26½ x 3 x 7/8
Shelf	1	44¾ x 12 x ¾ or 7/8
Wedges	4	2½ x 7/8 x ¾

The construction of the top rails is shown at *d* in the detail drawing. The only point calling for special attention is to see that the tenons are flush with outside of rail, being cut on only three sides, and the mitre at the end of each. The necessity for this mitre is shown in the drawing of the top of leg at *e*, where the two tenons are shown meeting in the blind mortises. The short rails are identical with those shown at *d*, except in length.

The detailed drawing of the legs is shown at *f*, and to make sure that the four are uniform, they should be laid out in pairs, the two at one end

together, then the second pair; and finally the two pairs must be compared to discover any possible

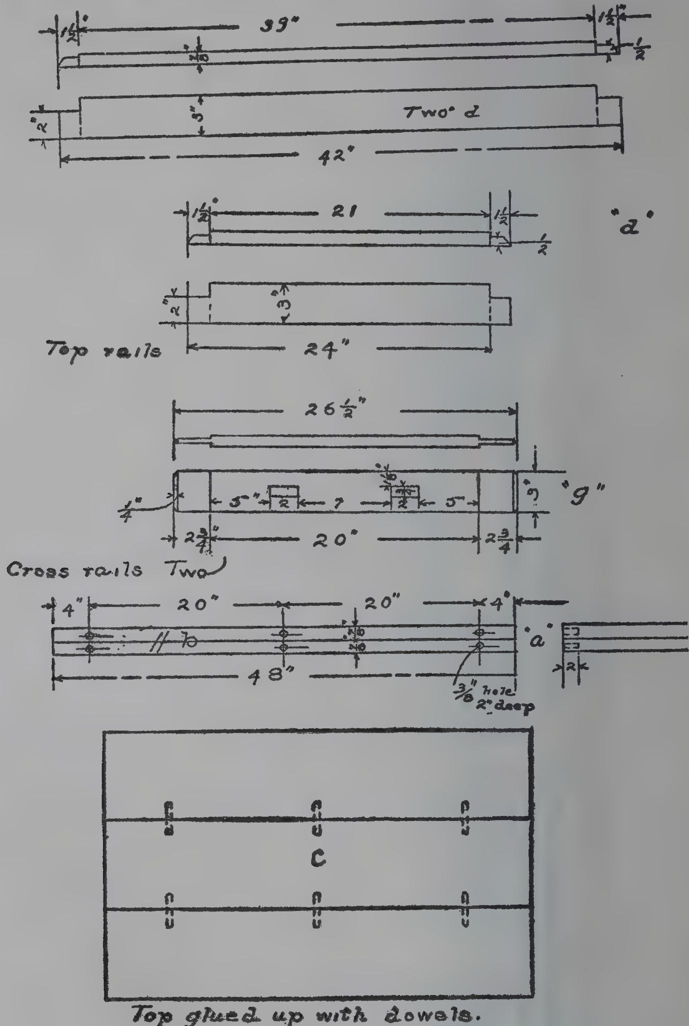


Fig. 196. A mission library table (*continued*)

inaccuracies. The cutting of the mortises may be hastened by boring several holes inside the lines from each side.

The drawing at *g* shows the layout of the lower rails, with tenons at the ends, and mortises on flat sides to receive the tenons on ends of the shelf. As in previous cases, these two pieces should be laid out together.

The most difficult work up to this point is the cutting of the two blind mortises at the top of each leg to receive the mitred tenons. This operation could be simplified, by replacing the mortise and tenon at that point by a dowel joint, but it would no longer be genuine mission furniture, and a much weaker form of construction.

The drawing of the long shelf explains itself, two tenons being cut at each end and a rectangular hole cut through each tenon for the wedge. The tenons are shown with a slight bevel, which is cut with a chisel when all other work is finished.

Before proceeding further, it will be wise to try and fit all the joints. Number or letter the two parts of each joint, as it is finished, to assist in the final assembling. This process of fitting should take some time, for it cannot be hurried safely. When it is finished, the way to fasten the top to the frame should be considered.

Several methods are in use, and two are shown at *h* and *i*. At *h* a hole is bored at an angle in the rail. As it goes only part way through, it provides a shoulder for the screw head, and the screw is driven through a hole drilled for the purpose into the solid top.

If this method is used, at least ten screws would be needed for a table of this size, three on each side and two on each end.

The method shown at *i* is probably the better of the two. Blocks of wood of the shape and size given in the drawing are made and fitted into a groove ploughed in the rails.

This groove may be ploughed the full length of rail, or cut out for an inch or two with a chisel. The tongue and groove should fit snugly, and the block be securely fastened to the top with screws. Two blocks on each side and one on each end will be sufficient.

A simple method is to fasten top and frame by angle irons 2 inches long, on the inside.

This question having been decided, take the glued-up top from clamps and dress down to size. The under side should be trued up enough to fit neatly over tops of legs and rails, and the upper side should be planed, scraped, and sand-papered.

The final assembling should be done in this order:

Assemble the two ends separately. Each end consists of two legs, a top and a bottom rail. The mortise and tenon joints should be glued, and a clamp used at top and bottom. Test for squareness. When dry, remove clamps, insert shelf tenons and those of top rails in their mortises, and clamp lengthwise. Drive a wire brad through each tenon, from the side of leg least conspicuous, and set with nail punch.

Put on the top, and level bottom of legs where necessary. Remove all traces of glue, and fill brad holes with putty, coloured same as stain to be used.

Place wedges in mortises provided, and fasten each one with a small brad driven through the side of shelf tenons. Stain and polish.

THE TEA TABLE

This table is made low purposely, the legs being exactly two feet in length. The construction consists of four legs, two sets of cross rails, and a circular top two feet in diameter. As this top is too wide to be cut from one board, joint two pieces of $\frac{7}{8}$-inch stock, glue together, and place in clamp. The joint may be strengthened with dowels, as in previous cases. (Fig. 197.)

By proceeding in this order — gluing up first —

no time need be lost in waiting. Square up the four legs and lay out the eight mortises, placing the four pieces in a vise or clamp to insure uniformity. Cut the mortises and lay the legs one side. The two sets of cross rails are to be halved at the centre, and

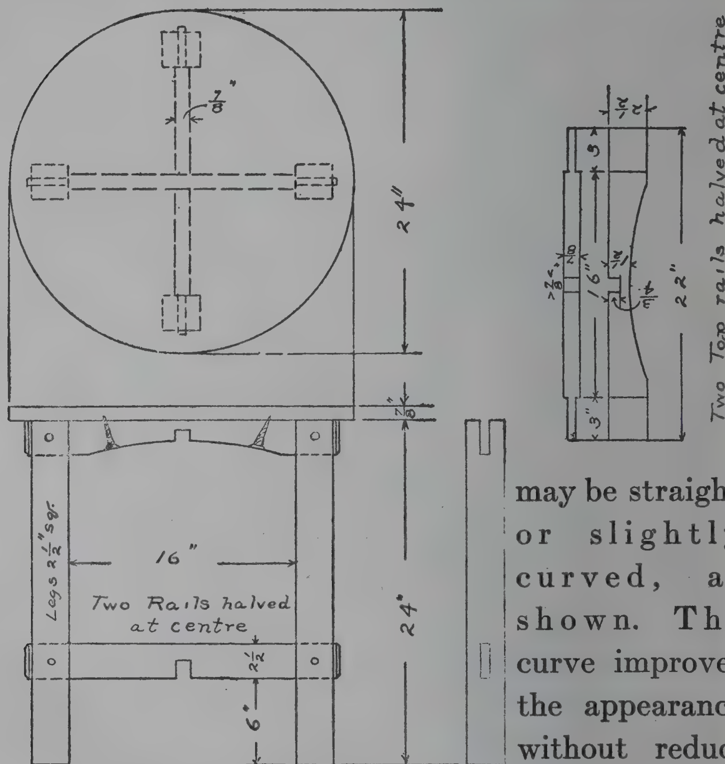


Fig. 197. A mission tea table

may be straight or slightly curved, as shown. The curve improves the appearance without reducing the strength seriously, but if this form is decided on, the curve must be cut before laying out the halved joint.

After finishing the joint, the two rails of each set are clamped together and tenons laid out. Remove from clamp or vise and cut tenons. Test each set to make sure the halved joint at centre is satisfactory, and insert tenons in the mortises. Draw bore and fasten with round pins of the same material as the legs.

Before fastening the top rails in position, drill and countersink two holes in each piece for the screws, in the position shown in drawing. The bevels on end of tenons should be cut with the chisel before the final fastening.

The two boards composing the top when removed from clamps should be dressed flat on both sides, tested with a straight edge, and circle laid out with steel dividers set at a radius of twelve inches.

Saw close to this line with turning saw, chisel to line, and smooth with spokeshave and sand-paper block — a piece of pine 3 x 2 x 7/8 inches, with the sand-paper tacked on the 7/8-inch edge. Scrape and sand-paper top.

To fasten this top to the frame, lay the top upside down on the floor, and set the frame, inverted, on it. Measure carefully to locate the frame in proper position, and fasten with four 2 1/2 or 2 3/4 inch flat

head screws. Assuming that all parts of the frame have been scraped and sand-papered before assembling, the table is ready for polishing.

Oak is the wood commonly used for this piece of furniture, but if well seasoned, chestnut is lighter in weight and just as satisfactory as to grain and finish. (See staining and polishing.)

Sometimes in mission furniture the legs of the table are allowed to come up through the top. This design is shown at Fig. 198. The diameter of the top is 24 inches, but the height is increased, as this is designed as a centre or reading table. On account of the support furnished by the shoulder at the top of legs, the top set of rails is omitted, and the fastening made by four angle irons securely screwed to the top and legs.

This table, on account of the greater span between the legs, is as stable as the previous design. The cross rails are halved, and may be straight or curved on under side. If desired, a commodious shelf may be had by fastening a circular piece 19 inches or less in diameter to the top of cross rails. This will need to be glued up and cut like top piece.

The square tenon at the top of legs is shown in the detailed drawing, and care should be taken in laying out to insure the distance from the shoulder

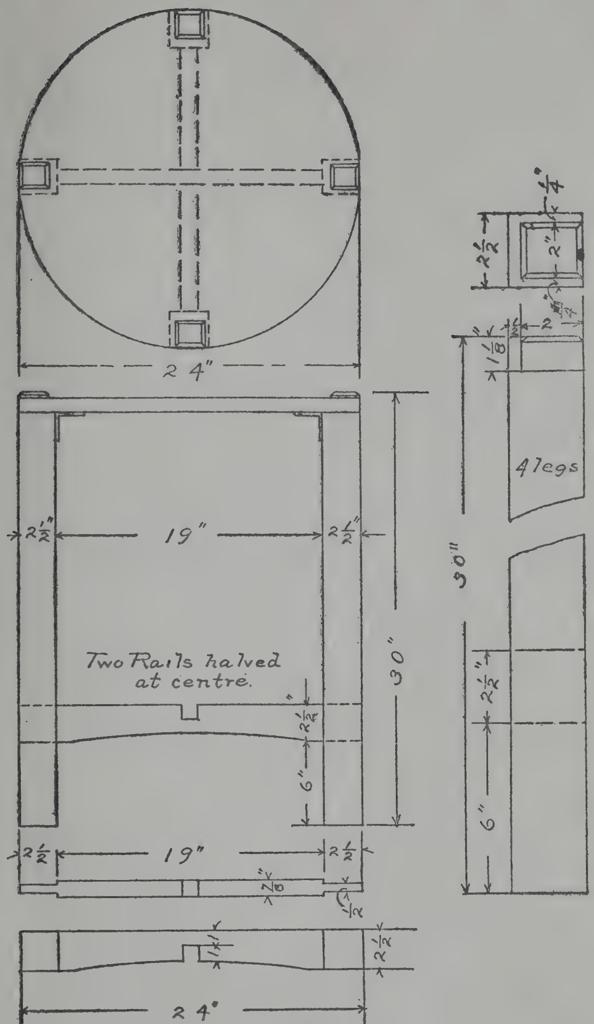


Fig. 198. A mission style centre table

to bottom of leg being alike on all four, if the top is to be level.

After gluing up and dressing down the top, lay out circle and two-inch square openings for the tenons. Test these squares carefully before cutting, to make sure they are equally spaced, saw out circle, and finish as in previous table. Saw out the squares close to line and finish with chisel. In putting on angle irons, screw them to the top first and press it tightly down on the shoulders before fastening to legs. A strong cleat 18 or 20 inches long fastened to under side of top across the grain with four or five screws will help to prevent warping, but is not absolutely necessary. If the circular shelf is added, it is to be fastened to cross rails by screws from the under side through drilled holes.

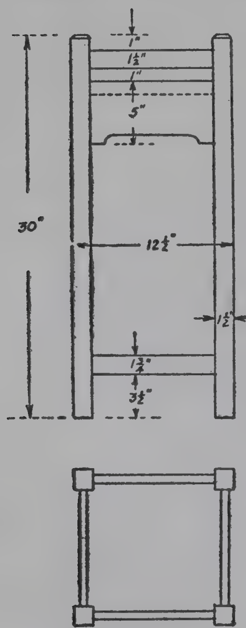


Fig. 199. Mission plant stand

DESIGNING MISSION FURNITURE

Boys who have followed the preceding instructions will be able to plan and construct the following designs without detailed explanations.

The two drawings for plant stands are in the nature of suggestions, and although taken from pieces actually made they show the great difference in form that is possible in meeting the same conditions.

Fig. 199 is thoroughly representative of the so-called mission style with its mortise and tenon joints and straight square legs.

The shelf for holding the jardinière is indicated by dotted lines, and it is held by cleats fastened to the sides by flat-head screws.

A dark finish, antique or rich brown, is appropriate for either design. Fig. 200 shows a radically different form. The shelf is octagonal or square with the corners cut at 45 degrees to fit the legs.

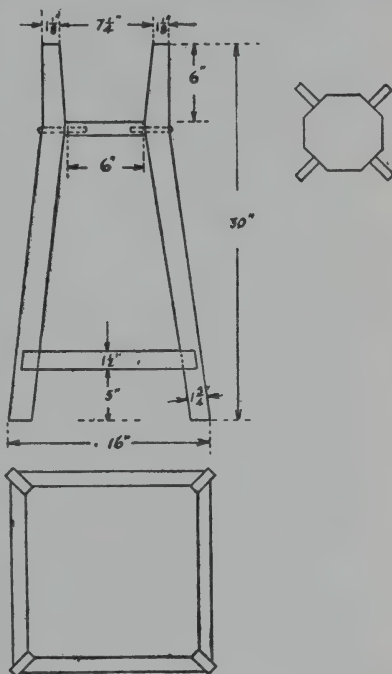


Fig. 200. Design for a plant stand

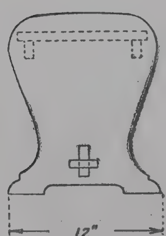
The detail view shows the arrangement of lower rails meeting the legs at the same angle. The ends

of rails are mitred and secured by wire nails set below the surface and holes filled. The fastening between upper shelf and legs may be either round-head blue screws or dowel pins of the same material as the legs, with the outer ends slightly rounded.

The shape of the legs makes this design weaker than Fig. 199, but their spread results in a more stable base and makes this stand less liable to upset.

The foot rest (Fig. 201) is to be provided with a cushion covered with leather nailed on with large-head craftsman nails.

The cushion may be filled with hair, excelsior, or even fine shavings, securely sewed in a cover of



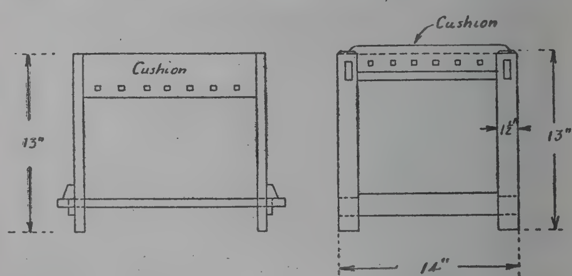


Fig. 201. Foot rest

Fig. 202. Footstool in mission style

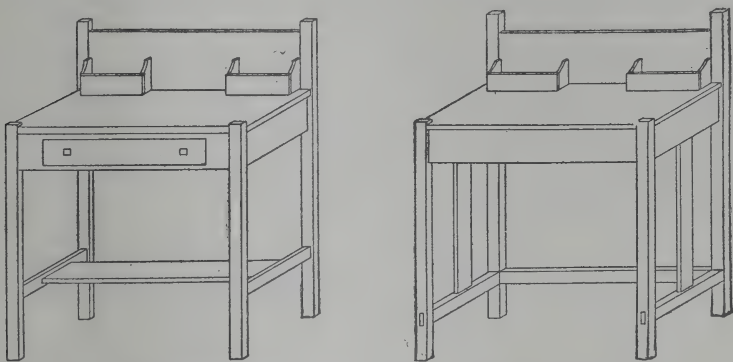
ticking and held in place by the leather cover. The leather must be brought down and nailed to the lower edge of the cross rails. Fasten the top to cleats screwed on inside of ends.


Photograph by Helen W. Cooke

Assembling and Finishing

Fig. 202 shows the same problem worked out in straight lines, the leather being nailed to all four top rails.

Each of these pieces of furniture suggests a new one, and chairs, settees, umbrella stands, writing



Figs. 203 and 204. Mission desks. A study in design

desks, etc., may be made along the same general lines.

The plant stand (Fig. 199) suggests the umbrella rack. The shelf is simply shifted from the top to bottom and provided with a brass tray to catch the water. Valuable suggestions for such furniture may be obtained by consulting catalogues of furniture, and by constant observations of well-made pieces.

These designs should never be copied, but used only as aids to the working out of original ideas.

The typical writing desk shown at Fig. 203

illustrates this point. While fairly well proportioned, the legs could well be heavier. The drawer is also faulty. Its position makes it necessary to move away from the desk in order to open it. The lower cross rail will be a nuisance when sitting close enough to write and other features might be criticised. Whether your design will be a success or not depends on the clearness with which all these details are thought out. Fig. 204 shows several of the above defects corrected.

XXVI

POULTRY HOUSES

THERE are a hundred ways of raising chickens, and ninety of them are wrong.

This is not a treatise on poultry raising, for there are many elements which enter into the problem — incubation, brooding, feeding, etc. But assuming that one of the main points aimed at is the production of eggs in winter, when they are scarce and expensive, the *housing* of chickens is admitted by poultry raisers to be one of the first considerations.

The house should be sixteen feet deep, should face south, and no glass should be used in its construction. A window nine or ten feet long by two and a half feet high placed four feet above the ground is recommended, and it should be covered with netting or chicken wire on the outside, but left open all day, even in zero weather. It is closed at night, by a screen of canvas or duck fastened to a light wooden frame. The frame is hinged at the top, and, hooked up to the ceiling during the day.

The following description is taken from the experience of several poultry men who have been successful, and have made money by selling eggs.

The principle of this construction is that ventilation is a prime necessity, and that dampness is the one thing to be avoided. With these objects attained, chickens will stand almost any amount of cold, and with proper feeding and the strictest cleanliness, egg production will continue throughout the winter.

Some successful men insist on a wooden floor, others recommend one of gravel ten inches deep. The construction given here calls for the gravel floor on the ground level.

Many recommend a litter of straw ten inches or more deep on the gravel. The morning meal is thrown on this litter so that the chickens are forced to scratch for their breakfast, getting the blood in circulation by this early morning exercise.

As the method of building this house is typical of many outdoor structures, it will be taken up in detail. It would make an excellent work shop or cabin, with a few modifications, such as a floor of boards, and the addition of a few windows. Before it is finished the builders will probably regret, as

our boys did, that it was to be used by their chickens instead of for themselves. (See Fig. 222.)

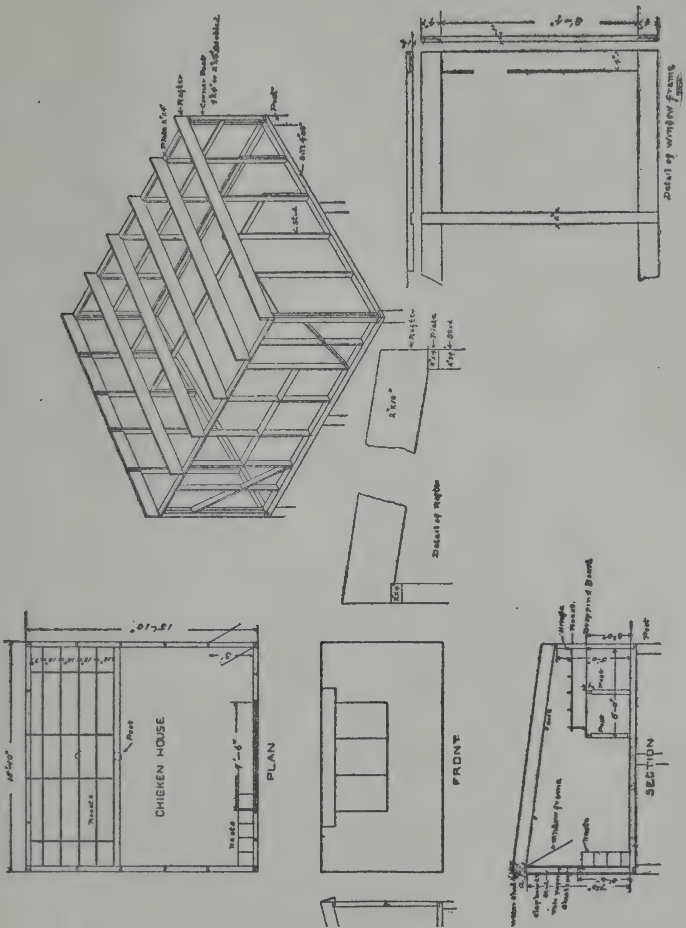


Fig. 222. The poultry house.

Set eight locust or chestnut posts in the ground and saw off six inches above the lowest point.

Of course one will be required for each corner, and one for the middle of each side. See that the outsides of posts measure 15 feet 10 inches over all measurements.

Square the corners by the 3 – 4 – 5 method, laying the 4 x 4 inch sill pieces on top of posts while doing this. The sill is put together with halved joint, and spiked to the posts with twelve-penny wire nails. The corner posts are 4 x 4 inch spruce, with square ends toenailed to the sill.

Plumb these posts, and tie in position by temporary braces, using for this purpose shingle lath or strips of boards.

The plates along front and back are 2 x 4 inches, nailed to posts from the top.

The frame may now be finished by placing the 2 x 4-inch studding, toenailing to sill and plates on the ends, and sill and rafters on the sides.

The frames for door and window are shown in the illustration.

The rafters spaced three feet apart are 2 x 8 or 2 x 10 inches. This large size is due to the long span of sixteen feet, with no middle support from underneath.

The ends of rafters are cut to fit snugly over the plates, as shown, and sawed straight up and down

to correspond with vertical walls front and back. No overhang is provided for the roof, as commercial roofing paper is to cover the whole outside of the house. In case it is to be used for other purposes than poultry raising, this feature should be modified, and the rafters allowed to project both front and back.

With the rafters nailed in position, permanent braces may be put in at the corners, as shown in the drawing, and temporary braces removed.

If the building is to be used as a shop, a second door directly opposite the one shown is recommended. For this purpose the position of the work bench would be on the front directly under the long window, and the two doors would then be in the proper place to permit the planing of long boards.

When the frame is finished, the question of siding must be taken up. If the original purpose of the building is to be carried out, poultry experts claim that a double wall is very desirable as a barrier against dampness, which arises primarily from the exhalations of the birds. If the walls are cold, this dampness will condense on them, while with a double wall this does not take place, as the dampness escapes with the air. The outside casing may be of ship-lap boards or tongued and grooved material. For

a cabin or shop, novelty siding, clapboards or even shingles may be used. Bring the square ends of the boards flush with the openings for door and window, and nail to corner posts and studding with eight or ten penny wire nails.

Finish the two sides, sawing off the sheathing along the top of rafters. Cover front and back clear up to top of rafters, and bring ends of boards flush with outside of the side sheathing.

Several methods of finishing corners of frame buildings are shown in Fig. 223. At *a* is shown the corner of this chicken house. No corner boards are used over the outer sheathing, as the whole structure is to be covered with roofing paper.

At *b* is shown the finish for a stable or cheap cottage, with outside trim nailed over the sheathing. This is the cheapest, easiest, and poorest method of corner finish for ordinary outhouses. At *c* a better method is shown, with trim nailed to the posts, and clapboards fitted up close to it and nailed to corner posts. A still better finish is shown at *d*, where the trim is nailed to posts but not lapped. The angles between corner trim filled with a quarter round moulding make a good joint and a neat finish. If the double wall is to be used, a second boarding is made on the inside of studding and under side

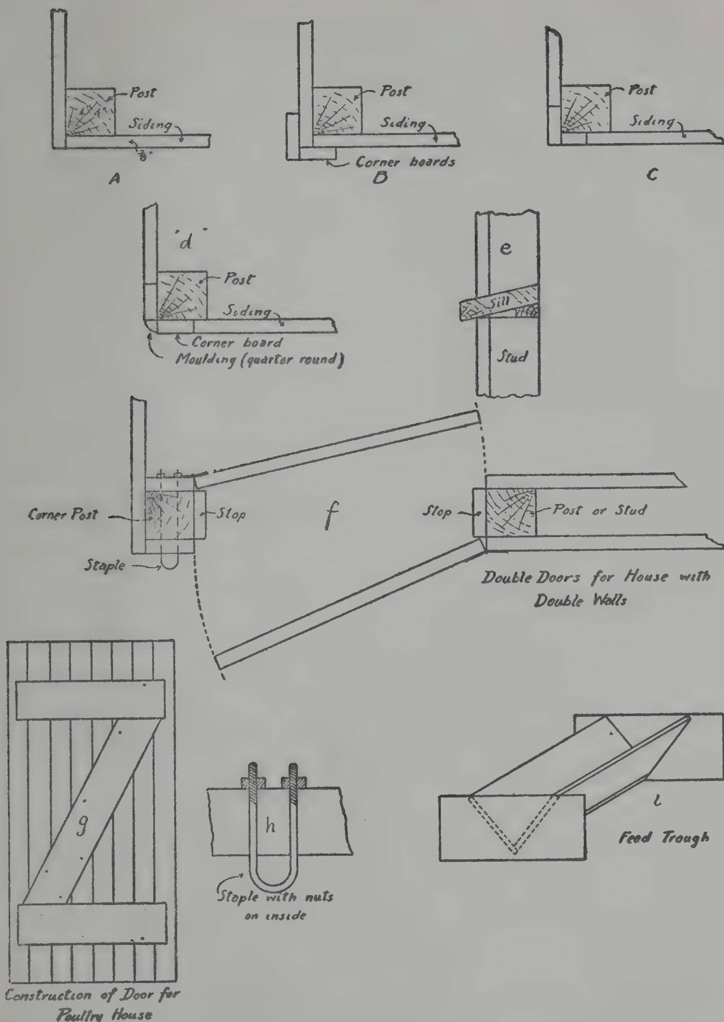


Fig. 223. Details of poultry house

of rafters, first covering the space with building paper tacked to the inside of studding, and nailing the boards — either ship lap or tongue and groove — to the frame work.

Door and window sills are made with an outward slant to provide a water table. A cross section of window sill is shown in the detail drawing at *e*. As there is no window in this building except the canvas screen, the construction of a window frame is not necessary. If the double wall is made, a double door, one opening in and the other out, will be in order. The outside door, flush with outer sheathing, and the same arrangement inside are shown at *f*.

A door sill will not be necessary, and the construction of the doors is shown at *g*. The material is tongue and groove boards fitted to the opening, so as to close easily, yet to provide for expansion in wet weather, and held together by heavy cleats 3 x 7/8 inches on the inside, as shown. The inner door is fastened by a hook and eye, and the outer one with hasp, staple, and padlock.

As the window opening is covered with wire, the only way a thief can get in is by cutting the wire and canvas or by drawing the staple. The latter method can be prevented by the use of special staples, with

threads cut on each end, and fastened on the inside by nuts, as shown at *h*. These staples are sold at all hardware stores.

The construction of the frame for the canvas screen is shown in Fig. 222. The lap joint is used throughout, and the outside dimensions are two inches greater than the window opening. Tack the canvas or duck to the side of the frame next the window, and provide two hooks and eyes to fasten it down at night. Strong iron butt hinges should be used on this frame, and heavy T or strap hinges on the doors.

The outside of the house is finished, except for a water-shed over the window, and the cover for the entire outside of strong roofing paper. This is sold usually with a special cement for making tight joints and with tin washers for the nails. The water table is simply a board projecting at an angle and fastened to triangular brackets, as shown at *a* (Fig. 222). The roofing paper brought down over this board, and tacked to the under side or edge, makes a water-tight joint.

The inside woodwork consists of roosts, dropping platform, and nests.

The dropping platform is a floor of tongue and groove boards, placed three feet from the ground on posts, and extending the full length of the house.

The roosts are fastened to a strong frame, as shown in drawing, and the frame — in sections—is hinged at the back. Each morning this frame is raised, hooked to the ceiling, and the dropping platform cleaned.

The construction of the nests is a subject on which poultry experts differ widely, but whatever form is adopted, the material may usually be obtained from old boxes or packing cases.

The outdoor runs for summer consist of wire netting fastened to chestnut, cedar, or locust posts. If other woods are used, the lower parts should be coated with creosote. This is also a good disinfectant, to be used for cleaning the roosts occasionally.

Many accessories for the poultry house may be made of wood, but opinions of specialists are so antagonistic that it is hardly safe to advocate any one type. A feed trough is shown at *i* (Fig. 223). It may be made from box material, and consists of two boards nailed together at right angles, supported at the ends by two horizontal pieces nailed on. Brooder houses, feed, and incubator houses, and the many other details of poultry raising are well within the power of any careful boy, and the designs should be selected from the expert whose system he has decided to follow.

XXVII

HOUSING OF OUTDOOR PETS

THE care of rabbits, guinea pigs, and other pets becomes of absorbing interest to every boy at some time, and he is fortunate indeed if he has room outdoors to engage in this pastime properly.

The comfort of the little animals, and their protection from their natural enemies, the cat, dog, weasel, etc., should be well looked after. Fig. 224 shows a very simple and convenient house for animals which do not gnaw through wood, as the rabbit and guinea pig.

These two animals will usually live together peaceably, except when breeding. The mothers become sensitive and jealous of all strangers when raising a family. The house proper has a sloping roof, which is hinged to provide a convenient method of reaching any part of the inside.

The large space covered on all sides by wire netting is the yard, or runway.

The front of the house should face south, and be

covered with netting, except the door, which slides up in the grooves provided, as shown in the detail.

The northern end of yard is boarded clear up to the top. This shuts off the cold north winds, and in that kind of a house rabbits will live the year round.

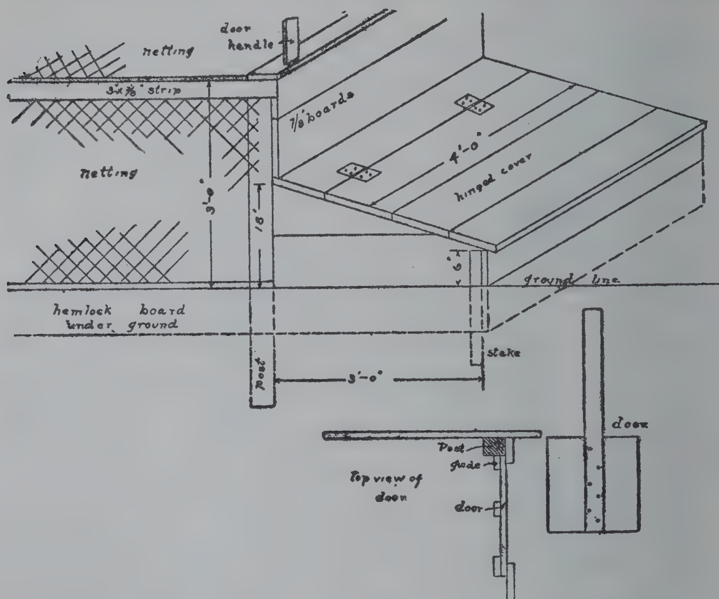


Fig. 224. Rabbit house

Guinea pigs will thrive in such a structure until the thermometer reaches zero.

These interesting and harmless creatures come from Brazil, and when the temperature reaches that point, it is better to take them indoors, as they catch cold and die of pneumonia, like human beings.

The runway is covered at the top with two-inch wire netting to keep out cats, who seem to take delight in killing both pigs and rabbits.

The upright corner posts should be set at least two feet in the ground, braced along the top by strips, to which the netting is fastened with staples, or double-pointed tacks.

A hemlock board should be set in the ground all around the yard, with a projection of an inch or two for securing the netting at the ground line.

Hemlock is cheap and will last longer in the ground than spruce. If the rabbits start to burrow, they become discouraged by finding this board in the way on every side. These planks or boards may be rough-sawed lumber.

The inside of the house should be coated with creosote and painted outside a bronze green. A dark-coloured house is warmer than a white one, as may be easily proved by placing a thermometer, first under a black hat, then under a white one. This is probably the reason why people in the tropics wear white clothing.

A door the full height of the yard should be provided at the far end, as it is sometimes necessary to get in for cleaning or other purposes.

The hinged roof should be made water tight by

covering with some form of commercial roofing paper, or by using tongue and grooved boards well painted.

The door sliding in grooves, as shown, has a long handle, which projects up through the top of the runway, so that it may be opened or closed from the outside. It can be made from box material.

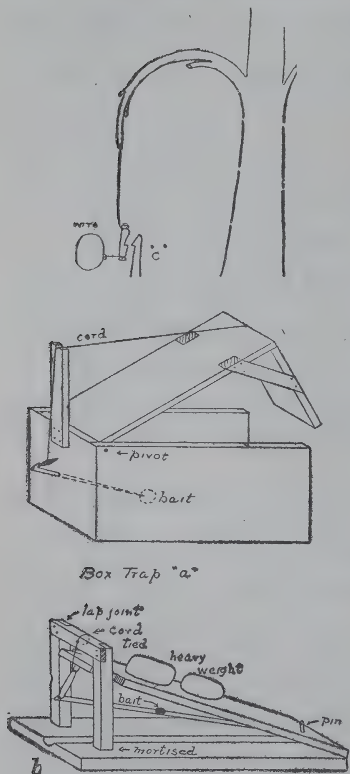


Fig. 225. Traps

A number of these houses may be placed in a row and allowed to open into a large yard, or there may be individual runs. The latter method is more satisfactory, as a large run can easily be obtained by providing doors between the yards.

In the country, where weasels, mink or other wild enemies bother the rabbits, they can be caught in traps. The ordinary box trap at *a*, Fig. 225, is designed to catch the animals alive. Its construction is clearly shown in the drawing, one end covered with

wire netting, or made solid, and the other provided with a door, arranged to drop easily in the groove when the trigger has been disturbed. The simple construction of the trigger is shown in the detail, while the bait is attached to a string. As soon as this is disturbed the door drops.

A typical dead-fall trap is shown at *b*. The weights placed on the sloping board should be heavy, as this trap is designed to kill its victim. For this reason it should never be used where there is any possibility of a pet cat or dog being caught. The trigger is very sensitive, and the slightest pull at the bait is sufficient to bring the weight down on the unfortunate animal.

The uprights should be mortised through the base board, and the cross piece at top halved to the uprights. The sloping board with weights fastened to it has a generous-sized hole fitted loosely over a dowel at the right-hand end of bottom board. A groove cut in the latter allows the weighted board to fit tightly when it falls, the dowel with bait dropping into the groove.

Fig. 225 at *c* shows a snare frequently used. It should be placed in front of a hollow log, box, or barrel, so that the animal must put his head through the loop of wire in order to reach the bait.

The first pull at the end of the trigger releases the spindle, and the bent sapling does the rest. The loop of wire should be held open and in position by twigs conveniently placed.

The killing of our few remaining wild creatures, however, should never be done for sport. It is excusable only when they become destructive or troublesome. Squirrels, rabbits, and chipmunks are much more interesting as friends than as caged or killed victims.

XXVIII

OUTDOOR CARPENTRY

OUTDOOR construction or carpentry, as distinguished from the indoor work of the cabinet maker, calls for a general acquaintance with tools, some mathematics, an elementary knowledge of the strength of materials, and a good supply of common sense. It demands also some knowledge of the effects of frost on foundations, and requires judgment in providing for the elements, wind, rain, snow, and sun.

Every building may be resolved into certain parts, such as foundations, framing, roof, door, and window frames, outside covering or siding, flooring, partitions, doors and windows, wall covering or ceiling, interior finish, hardware, etc. These will be taken up in their order.

FOUNDATIONS

These, like all details, depend on the size and purpose of the building. The method of setting a small building on posts has been explained under

our directions for making a poultry house. It should be used only for small structures, such as camp buildings, sea-shore cottages, and out-buildings. Brick, stone, and concrete all have their advantages, but for young builders, concrete is perhaps the best and easiest to handle. The woodwork necessary for concrete work is extremely important, and its possibilities have hardly been touched, even to-day. The box or form should present the smooth side of the boards to the concrete, and should be so constructed that the form may be readily removed after the concrete has hardened. This sounds like a simple matter, but it becomes complicated in many cases. The method of fastening the wooden frame to a concrete foundation is not strictly a matter for a book on carpentry and woodwork. In some houses the frame is simply laid on the concrete, and the weight of the building is trusted to keep it in place.

In the case of small structures this would not be sufficient, and a better way would be to imbed bolts in the cement before it hardens. Pass these bolts through holes bored in the sill, and fasten them with nut and washer on top, after the concrete has hardened.

Any foundation should be sunk at least three feet in the ground, otherwise it will be "heaved"

by the frost. Where a cellar is to be built, the foundation should be of sufficient depth to leave at least 6 feet 6 inches in the clear between floor of cellar and under side of floor beams, and seven feet would be better. If the foundation extends two feet above the ground, its bottom would be 5 feet 6 inches below the ground level.

The thickness of the concrete wall must depend on the size and weight of the building, and for a small cottage it should not be less than ten inches. Columns such as are used for pergolas make an excellent foundation for a small building to be placed on posts, as they do not decay and are permanent. They may be used to advantage for porches in place of wooden posts.

After a building is completed, some of the top soil removed in digging the cellar should be graded up to the foundation at a slight slope, to shed the rain and carry it away from the building. The box for a concrete wall should be well supported and braced, as the weight is sufficient to force the boards out of position. The method shown at Fig. 226 is frequently used, the 7/8 or 1 inch plank being supported by 2 x 4 inch studs, which in turn are braced as shown. On cheap work the outside boarding is omitted, the earth being shaved with the shovel as near the posi-

tion of outer casing as possible. Of course, this earth wall is only useful within a foot or so from the

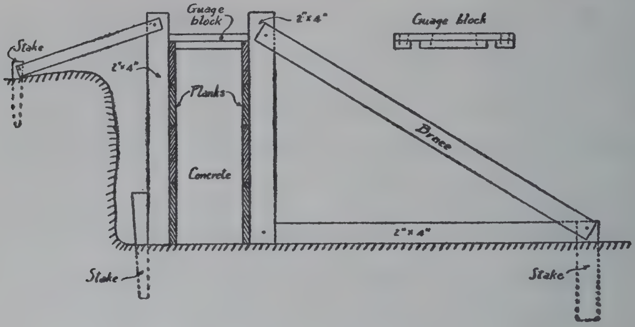
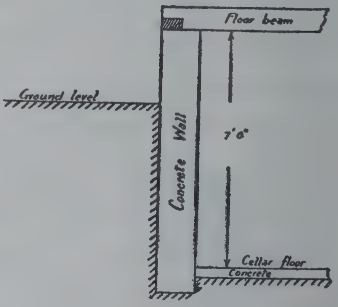


Fig. 226. Concrete foundations

surface. At this point the outer boarding must commence, and be continued to top of foundation. In order to have the foundation level on top, it is best to level the wooden form all around the four sides. If the concrete



is brought exactly to the top, and a straight edge is run along the edges of the form, the resulting wall must be level, provided the box has been made so. Concrete does not flow enough to level itself.

FRAMING

This is a subject on which volumes have been

written. The general arrangement with the names and sizes of the various members is shown in the drawing, a design for a small cottage, or bungalow. (Fig. 227.)

The heavy timbers forming the sill are cut to the outside dimensions of foundation and halved at the corners. Fasten the joints with ten or twelve penny nails. Cut all corner posts exactly the same length, toenail at corners to sill, and hold in position by temporary braces. Plumb the posts as the braces are nailed. Two boys must work at this job, one holding the plumb and the other nailing the braces. Cut and halve the ends of plate the same length as sill, and nail to corner posts. Cut 2 x 4 studs same length as posts, then nail to sill and plate 16 inches apart on centres. The openings to be left for doors and windows will break up the even spacing of the studs, but it should be made as uniform as possible. The spaces for door and window frames are to be enclosed with double studs to give the necessary strength. Corner braces are very desirable and in the old-fashioned braced frame were mortised into plate and post, and sill and post. (Fig. 227*a*.)

For a simple structure the necessary bracing may be obtained by "letting into" the studding 3 x 1 inch strips, as shown in drawing. To do this

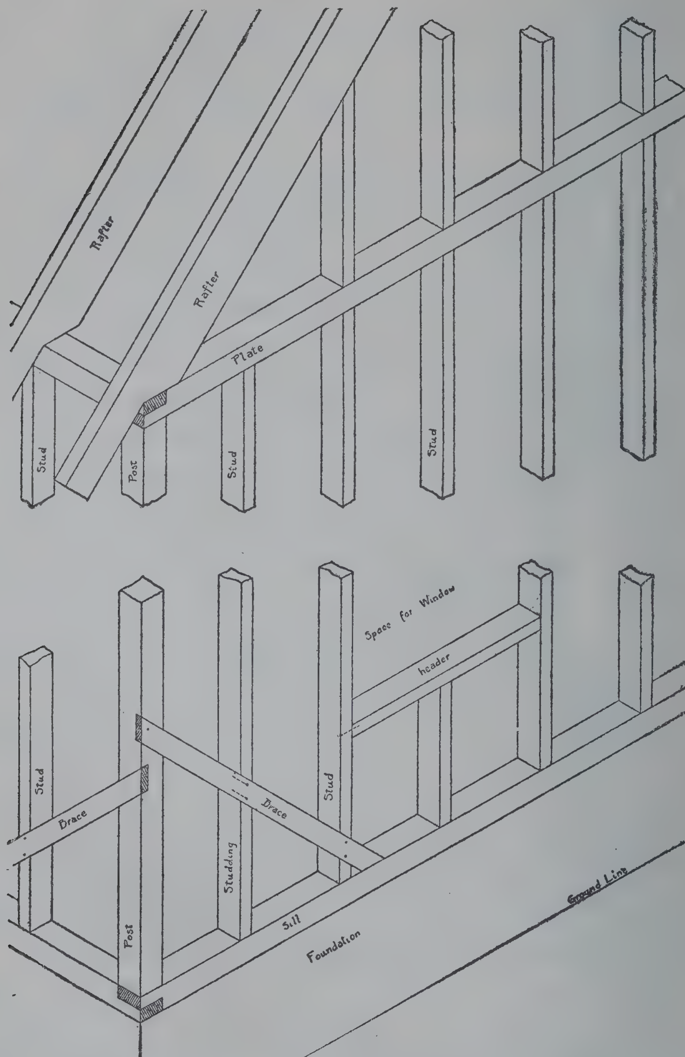


Fig. 227. Corner framing

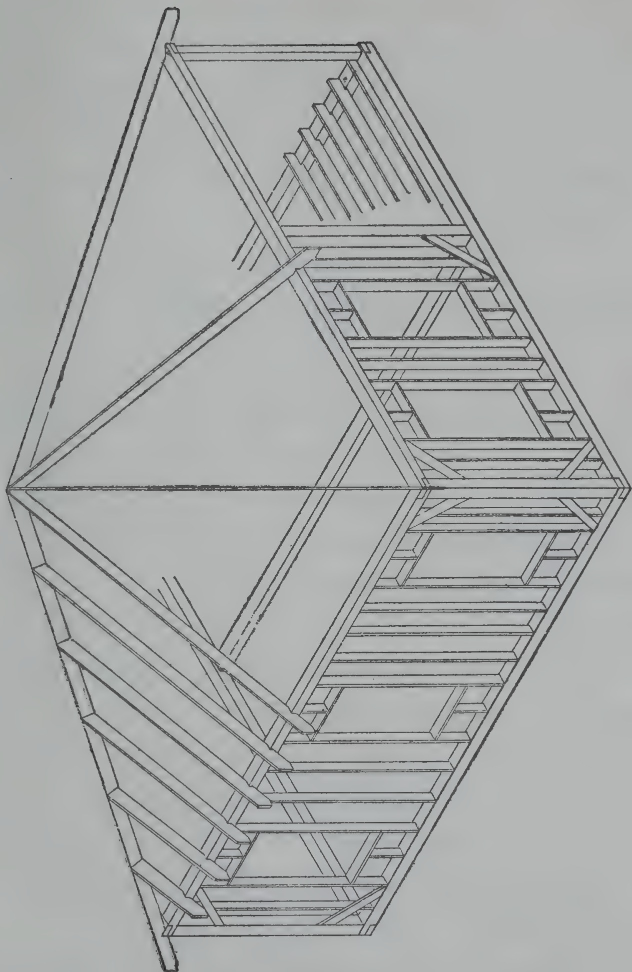


Fig. 227*a*. Frame of bungalow

hold the brace in the position it is to occupy, and make a pencil mark on both sides of it on each timber, sawing on the inside of these lines to a depth equal to thickness of brace. Remove the wood between saw cuts with a chisel. Test to see that brace comes flush with outside of studs, and nail securely in position.

When the frame is finished up to the roof the putting on of the siding may begin at any time.

SIDING

The outside of the building, siding or weather boarding, is an important item, as it is designed to protect the interior from sun, cold, and storms. It should be watertight, and may be made of various materials, put on in several ways.

In a house to be used in winter, the first layer should be of wide ship-lap boards. If put on diagonally it will act as a permanent bracing, and while this is the better way, it takes more time than horizontal siding. In either case nail to every stud and timber the board touches. Begin at the bottom of sill, break joints as the work progresses upward, and saw ends even with outside of posts.

At all door and window openings bring edges of siding flush with openings.

This inner siding is to be covered with building

paper, door and window frames set, tin flashing nailed over doors and windows, and outer covering put on.

Before proceeding with outside sheathing, however, the roof should be framed and covered.

ROOFING

It is a difficult matter to say that one part of a house is more important than another, as all parts are important, but a building with an unstable or leaky roof is an abomination. The framing of the roof must be strong enough to withstand gales, blizzards, drenching rains, and the weight of tons of wet snow.

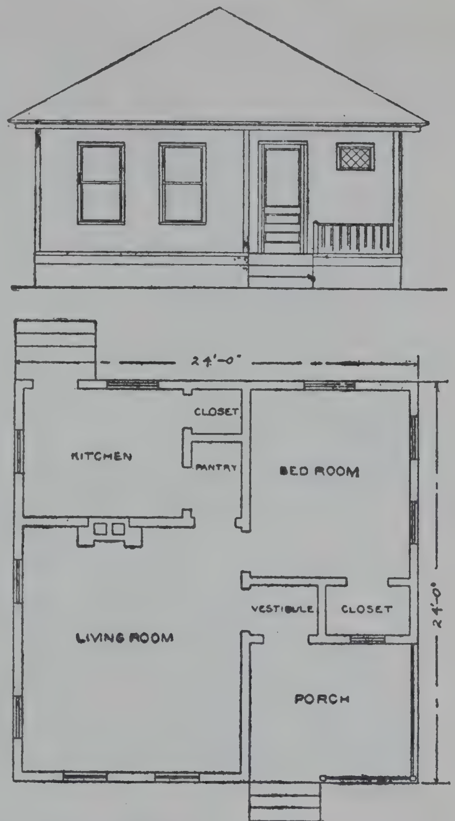


Fig. 228. Plan and elevation of a bungalow

As the method of shingling is well known and

presents no difficulties, it is only necessary to take up the subject of the frame. Boys will do well to confine their early efforts to plain sloping, or possibly hipped roofs.

These two styles are illustrated in Fig. 229.

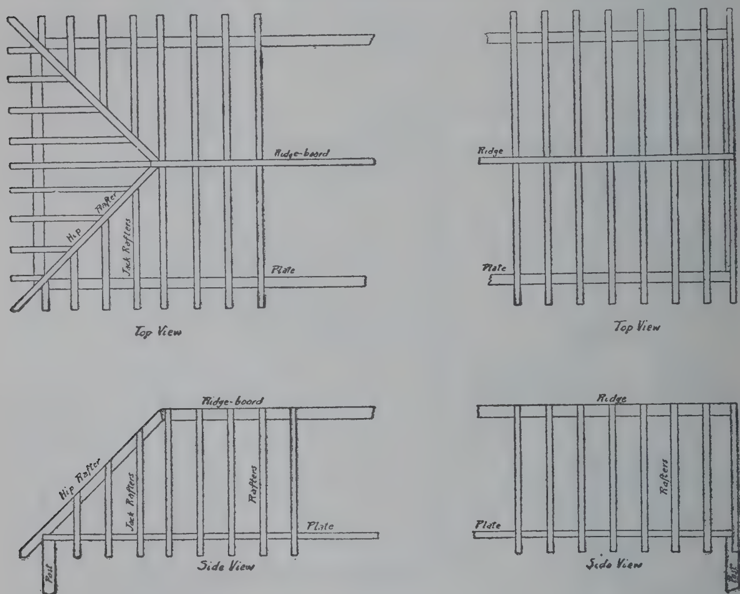


Fig. 229. Roof framing

The hip roof is the more pleasing and the more difficult to make. It reduces the attic space, if that is a consideration, and is harder to cover, or rather it consumes more time, as the question of whether a piece of work is difficult or not is really a question of whether or not you know how to do it.

The method of fitting the rafters is shown at Fig. 230. To find length of rafters, make a drawing to scale, in which $a-b$ is the height above plate level and $c-b$ half the width of the building measured on the plate or sill. The angle for cutting the mitre at the ridge may be obtained from the drawing, also the angles where the fit occurs at the plate. The length should be distance $a-c$ plus about two feet for the overhang.

A ridge board is usually inserted between the top ends of the rafters, and if made from a $\frac{7}{8}$-inch board, half an inch should be deducted from the length of rafters to allow for the difference.

The shape of lower end of rafters will depend on the kind of finish or cornice to be used. Two kinds are shown, the first and simpler being suitable for a barn or rough building.

On account of the high price of lumber, most boys will be obliged to use the most inexpensive style of finish.

Cut all the rafters the same size, and in erecting space them as nearly two feet apart as possible.

The first pair should be flush with the edge of plate and temporarily held in position by braces of shingle lath. It will be necessary in erecting the roof to place timbers and floor boards across the top

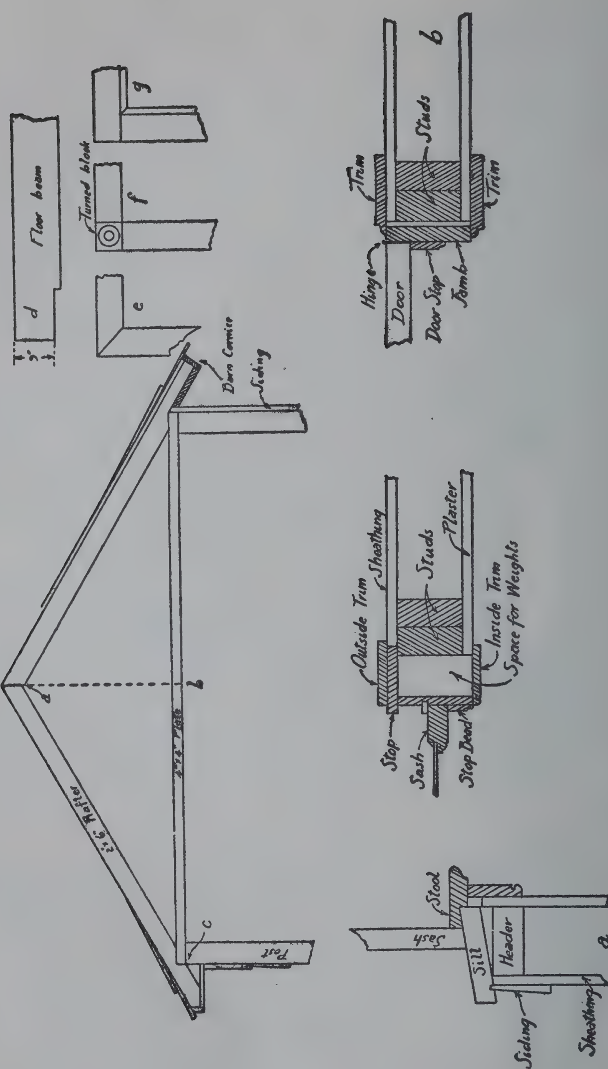


Fig. 230. Building details

of plate as a temporary floor to work on. Nail rafters to ridge board, and plate with ten-penny wire nails. Two boys must work together on this job, as every part of the work must be plumb.

When all the rafters are in place, cut and fit the short studs between plate and rafters, being careful to leave the openings for windows in the places called for on the plan.

The ship-lap siding may now be continued up to top edge of rafters, and sawed off even with upper edge.

If novelty siding is used without any under sheathing, it may be treated in the same way.

And now the roof is ready for the application of the shingles.

WINDOW AND DOOR FRAMES

These may be bought at the mill ready made. Very few carpenters make their own, as they are staple articles coming in standard sizes. Second-hand sashes and frames may often be bought at very reasonable rates, and it never pays to make either.

Set the frames in the openings left for them, and nail to studs. To make sure that the fit between frames and openings shall be right, it is best to take

the plans to the mill, and explain to the mill man just what is desired.

FLOORING

The floor beams may be set at any time after the frame has been erected up to the plate. As it will be necessary to work around inside more or less, the sooner they are in position the better. As these beams, supposed to be 10 x 2 inches, often vary in width, the floor is liable to be uneven, unless they are cut to fit the sill.

The amount cut out need not be very much, but a certain distance, say nine inches, should be marked from the top edge, and the lower corner cut out as shown at *d* (Fig. 230). This will bring all the top edges level, when they are in position.

The span of the floor beams — the distance from the sill to the next support — is important, as a floor is called upon sometimes to support great weight, as when a number of people are present, or a heavy piece of furniture such as a piano rests on it.

For floor beams 2 x 8, a span of not over twelve feet should be allowed; for 2 x 10 a slightly greater span may be used; but in either case the supporting beam in the centre of the floor should be halved into the sill with upper edge flush,

and should be supported at intervals of ten feet by posts set in the floor of cellar, or to a depth of three feet in the ground in case there is no cellar. This supporting beam should be placed when the sill is set on foundation. Nail floor beams to sill, and where the two beams from opposite sides of the building lap or pass each other over the beam in centre, nail them to each other and to the beam.

The flooring of tongue and groove stuff may now be laid, cutting ends square and fitting them up close to studding, or, what is still better, clear out to the sheathing.

The outside weather boards may now be put on, after deciding on one of the corner finishes described under poultry house. A flashing of tin — painted — must be placed over door and window frames, before the clapboarding or siding reaches these points. This siding is sawed off square, and makes a butt joint with the outer casing of door and window frames.

Some form of building paper is nailed to the first siding in good buildings, and pays for itself in the long run, by reducing the amount of fuel necessary to heat the building in winter.

If the house is a sea-shore cottage or camp only to be used in summer, both the paper and inner

sheathing may be omitted, and the expense account materially reduced.

The finishing of the interior may be left to the last, or done on stormy days. In the meanwhile, several important questions must be settled. One is the style of flue or chimney to be provided for the stove.

If the building is to be permanent, a brick chimney should be built by a mason. The danger of fire originating from defective bricklaying makes it advisable to have this work done by a tradesman.

For summer cottages or camp buildings a simple stove pipe can be used, but in any event it should be put up before the final roof covering is on, and "flashed," that is protected by tin laid over the roof timbers, and made watertight. This does away with leaks around the chimney, and the tin should be put on in such a way as to prevent the shingles from coming in direct contact with the hot chimney.

In these days of oil stoves, which are often used for summer cooking, the chimney may be omitted entirely. At the same time it must be remembered that there are cold, damp nights, when a stove is very comfortable at the shore or in the woods.

In regard to interior finish, if the walls are to be plastered, three coats will need to be put on by a

skilled plasterer. Thin yellow pine ceiling stuff, often used for camp buildings, is easily put on, and quite satisfactory. Laid on diagonally it is very pleasing, but the beads catch more dust than the vertical strips do. The latter method calls for horizontal strips laid between the studs for nailing, while a simple quarter round moulding laid in all corners gives the finish. A common practice in camps is to have no interior wall covering, but to leave the timbers exposed. For a dwelling, the frame should be of dressed lumber, which may be stained to conform with the general colour scheme.

The inside trim around doors and windows may now be put on. Three methods of finishing around windows are shown at *e*, *f*, *g* (Fig. 230); and one of these types should be adopted before ordering the trim from the mill. This work should be simplified as much as possible, not only to save time, but because decoration may well be left to pictures, artistic metal work, trophies; and things which are of interest from their history or association.

DOORS AND WINDOWS

If second-hand material is not used it is advisable to purchase these staple articles from a mill where they are made in standard sizes.

When ordered for certain size spaces they come a little too large. This allowance is for material to be removed in fitting. Inside doors are usually the last things to be hung. The windows should be hung as soon as the construction will allow it, in order to keep out rain.

Secure the pulleys for upper and lower sash into the window frame on both sides of parting strip about four inches from top of window frame.

Attach the sash cord and find its proper length by experiment. Tie securely to sash weights. See that the two sashes make a good, tight joint where they meet, and tack the window stop to frame with brads. The stop is to be ordered with the trim, and mitred at the top. The construction at the sill is shown at *a* (Fig. 230).

The arrangement of door frames is shown at *b*. After mitring the door stop, nail to door frame at a distance from its edge equal to thickness of door. Fit the door by planing to the space inside frame. The hinges are put on as shown, being sunk flush with edge of both door and door frame. When hanging the door, it is a good plan to place small wedges under it, to allow for the sag which will result as soon as its weight is thrown on the hinges.

Saddles are usually placed under doors to allow

them to swing clear of carpet and rugs. To allow for the thickness of these saddles, ¾ inch should be allowed between floor and bottom of door. The saddles are to be fitted around edges of door frame, making a neat finish.

For plastered walls a six-inch base board is necessary. This may be put on with butt joints and nailed to studding with small head finishing nails, as for all trim.

The base is usually topped by a base moulding mitred in the corners.

This style of construction is for a permanent house. For rough or temporary buildings, many modifications may be adopted. Batten doors, as described for the poultry house, may be cheaply and readily made.

Batten blinds made by the same method are very desirable for buildings like summer camps, which are to be vacant for long periods. This does away with the temptation some people find to break windows in unoccupied houses.

The siding for a small building may be of tongue and groove boards put on vertically, and now that lumber is so expensive these items are all important.

The lumber from packing cases may be used for making very many of the pieces of furniture in a

camp, such as stools, benches, tables, shelves, cupboards, bookcases, etc. Many of these useful articles can be made without tearing the boxes apart.

A very useful chest and seat combined may be made by fitting a box with a strong cover, strengthened by cleats on its under side and hinged with strap hinges to the back.

A cushion of burlap filled with shavings, straw, seaweed, or sweet grass will make this a very satisfactory settee, and the storage space inside will always be available. The outside of the box should be smoothed, all nail holes filled with putty, and the whole thing stained.

Very interesting panelling effects may be obtained by tacking on strips of the same thickness as the outside cleats.

Where the supply of wood is limited, many similar articles will suggest themselves to the young carpenter. The chair shown at Fig. 231*a* can all be made of wood from packing boxes, except the square legs. These may be obtained by sawing 2 x 4 inch spruce in half and planing smooth. The rails can be put on with mortise and tenon, or they may be gained into the legs and fastened with nails or screws. The seat

is built up of several pieces fastened to cleats on under side, with front edges rounded. To make this hard bottomed chair more comfortable, have a thin cushion of canvas or burlap fastened by a canvas cover and tacked to edges. The wide strip across the back may be treated in the same way. One coat of stain, or two of Japalac or some similarly prepared varnish will make a very serviceable finish for camp purposes.

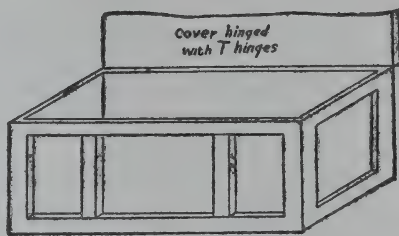


Fig. 231. Chest made from packing case

The proportions of a porch settee of the same general character are given at Fig. 231*b*. The legs may be cut out of pieces of spruce studding, and all but the long rails obtained from box material. These long pieces may be cut from ⅞-inch siding left over when putting up the cabin. Floor boards with tongue and groove planed off will answer very well.

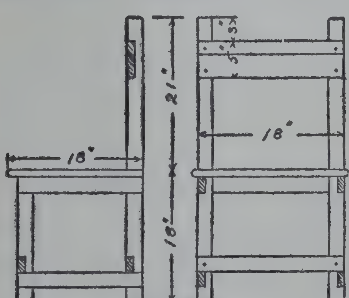


Fig. 231*a*. Chair

The long back strip will be more rigid if mortised into the ends, and the upright strips will be needed to give it the necessary strength.

One of the most comfortable articles for a camp

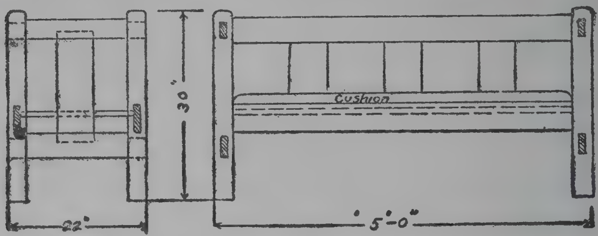


Fig. 231*b*. Settee made from box material

in the woods is the couch hammock. The materials required are:

A cot.
Four yards of strong canvas a yard wide.
Forty feet of clothesline.
Two chains or strong pieces of rope about 4 or 5 feet long.
A grommet set and some grommets.

Remove the legs from the cot. They are usually attached by bolts or rivets. If the latter, cut with a cold chisel.

Lay the canvas in one piece on the floor and place the cot at its centre. Make pencil marks at the ends to indicate where the fold begins as at B B (Fig. 232). Lap the canvas as shown and sew securely, leaving a space at the fold for the clothesline to pass through.

The square ends are to be hemmed and folded over pieces of broomstick.

With the grommet punch make holes through the canvas just below the broomstick and secure with the grommets. Make these holes about 5 inches apart. They are to hold the line which is to pass from iron fitting C through first grommet hole

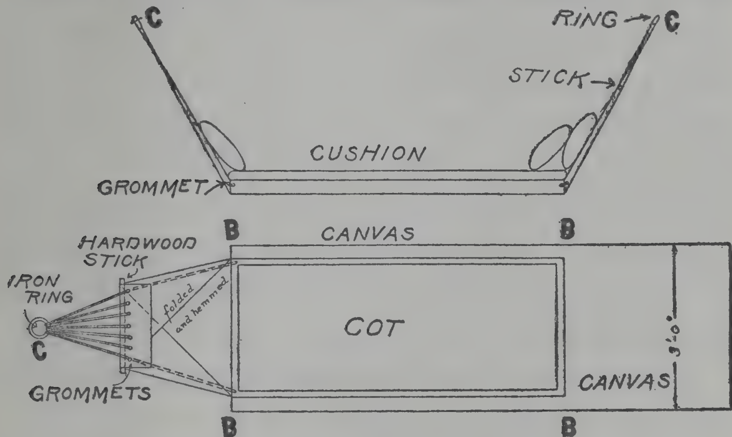


Fig. 232. Couch hammock made from a cot

and back until it has passed once through each grommet.

The fitting is found on all hammocks and can be taken from an old one, or an iron ring may be substituted. Before beginning to weave the rope through the grommets, pass its end down to B and make fast to a stout screw eye fastened to under side of frame of cot. This brings the weight on the rope

instead of on the canvas, an important item when five or six people sit on the couch at one time. Treat both ends alike. The canvas will be wide enough to fold up and entirely cover the edges of cot. When everything has been adjusted, fasten the chains or heavy rope to the iron rings, and secure to the trees or veranda columns by heavy hooks. A light mattress covered with blankets, or a specially made cushion to cover the whole cot, and several sofa pillows will add the finishing touches to a very serviceable and satisfactory article.

The cost will be about one third of those on sale, and this may be reduced 50 per cent. if a grommet set can be borrowed, as this is the chief item of expense, assuming that an old cot is used.

This hammock should not be left out in the rain, as its steel springs will rust.

XXIX

STAINING, POLISHING, AND FINISHING

THIS branch of woodwork is a trade by itself and under modern methods of specialization the men who do this work do nothing else. The methods of finishing are legion and every polisher has a few little "kinks" of his own which he regards as trade secrets.

The personal equation enters very largely into the work, and if twenty boys have a given method explained to them and they all polish, say, a box of the same size and material, there will result twenty different kinds of polished surfaces.

This is due to difference in temperament. Some boys are patient and painstaking. Others are nervously anxious to get through and see how it looks. It is a fact particularly true of finishing that it cannot be hurried without endangering the result. Every coat must be thoroughly dry and hard before the next one is put on. Different woods require different treatment, and the elements of good taste, colour, and harmony all enter into the problem.

These statements are not made to discourage the young woodworker, because finishing can be done well by any boy who will use reasonable care, but to emphasize the fact that it is poor policy to make a fine piece of woodwork and then spoil it at the last moment by hurry.

Staining is something on which opinions differ greatly. Some artists claim that only the natural colour of the wood should be used, but a great deal of staining is done, and we must leave artistic arguments to others.

The extent to which staining is carried may be illustrated by the following finishes used on one kind of wood—oak:

Golden oak	Antwerp oak	Rotterdam
English oak	Ox blood	Antique
Forest green	Weathered oak	Cathedral oak
Austrian	Flemish brown	Flemish green
Silver gray	Sumatra brown	Filipino
Mission oak	Malachite	Fumed oak
	Bog oak	

The writer believes that staining to make imitations is wrong, such as staining cherry or birch to give the impression of mahogany.

The list of materials for staining is very bewildering, and it is advisable to reduce the list to a few reliable ones and learn to use them well. They may

be divided roughly into three classes: oil stains, water stains, and stains produced from drugs or chemicals.

Oil stains are dry colours ground in oil such as chrome yellow, Prussian blue, burnt umber, burnt sienna, etc. When preparing one of these for use, thin with turpentine and linseed oil and apply with a brush. After it has stood for a few moments rub off with a piece of cotton waste or rag.

Water stains are colours dissolved in water.

After applying this kind allow it to dry. Sand-paper the surface flat and apply a second coat of half the strength.

Stains produced from drugs and chemicals include such materials as logwood, bichromate of potash, ammonia, iron sulphate, acetate of iron, etc.

The preparation of the surfaces to be finished is very important and means the removing of any defects, such as scratches, by means of plane, scraper, and fine sand-paper.

These defects always show much more prominently after polishing than before, so that too great pains cannot be taken in preparation. Assuming that the surface is ready, the first question to be considered is whether the wood is open or close grained. If an open grained wood, a coat of filler may

be used; if close grained this may be dispensed with. The following list will enable the beginner to decide:

Open grained woods requiring filler:

Oak, ash, chestnut, mahogany, walnut, butternut.

Close grained woods; no filler required:

White wood, pine, cherry, birch, beech, gum, sycamore or button ball; maple, cedar, cypress, red wood.

Filler may be made at home, but it is a staple article to be found in paint stores and it is advisable to buy it ready made. It comes in paste and liquid forms, and the paste is recommended. It must be thinned with turpentine to the consistency of cream and applied with a brush. As soon as it begins to dry, rub off the excess across the grain with a handful of excelsior, waste, burlap, or rags and allow it to stand over night to dry.

When the wood is to be stained the colour is frequently mixed with the filler.

The object of all this is to fill up the pores of the wood to give a flat, solid surface for the polishing. Sometimes even on open grained woods filler is omitted entirely.

Suppose that the work in hand is a footstool or tabourette made of oak and we wish to give it a forest green finish.

The process would be as follows:

Photograph by Helen W. Cooke

Staining and Polishing

Prepare the stain by mixing a small quantity of chrome yellow and Prussian blue on a piece of wood. Mix thoroughly with a putty knife or old chisel and thin with boiled linseed oil and turpentine; add blue or yellow until a beautiful dark green is obtained. Add this to the filler, using turpentine for thinning, until the whole mass of liquid is the desired colour and as thick as cream. Paint the footstool all over with this filler. As soon as it starts to dry, rub off as explained.

The next day sand-paper smooth and give a coat of shellac. When hard, sand-paper flat and give a second coat of shellac.

From this point on the process depends on whether a glossy polish is desired or a dead flat surface. For an article of furniture like a footstool a highly polished surface would be a mistake, as it would soon be scratched, and while furniture is not to be abused, it is to be used, and shoe nails make scratches.

A dead flat surface may be obtained by rubbing down the third coat of shellac with fine-ground pumice stone or rotten stone and water. If too flat, rub the surface with raw linseed oil and wipe dry.

Some boys will obtain a better finish with two coats of shellac than others will with four.

After the first coat of shellac, varnish is often used for the remaining coats, but it takes much longer to harden and requires careful handling.

Shellac is a product obtained from certain trees in the Orient. It may be bought in the dry state at paint stores and dissolved in alcohol. Grain alcohol is the best and most expensive, but wood alcohol is cheaper and will answer all ordinary purposes. The shellac may be bought in cans all ready for use, and there are two distinct kinds — orange and white.

White shellac is the more expensive, but should be used on light-coloured woods, such as maple, to avoid spoiling the colour.

Varnish comes in so many grades and kinds that it is best to go to a reliable dealer and tell him just for what purpose you expect to use it. There are outside varnishes, rubbing varnishes, light flowing varnishes, etc.

When by exposure it becomes thick so that the brush drags, it should be thinned with a little turpentine.

There is a great difference in the methods of using shellac and varnish. The former being dissolved in alcohol evaporates quickly, so that it must be put on thinly and as rapidly as possible.

Varnish, on the other hand, may take forty-eight hours or more to dry, so that the brush can be drawn over the surface several times to remove air bubbles. It is not possible to do this with shellac. The brush used in shellac should never be laid on the top of the jar or can, as it will harden in a very short time. The care of brushes is an important item. Varnish brushes should be cleaned with turpentine, shellac brushes with alcohol, and when cleaned it is better to keep all brushes in a pail of water than to allow them to become dry.

The jar or wide mouthed bottle used for shellac should be kept covered else a great deal will be lost by evaporation. A jam jar makes a convenient receptacle for this, as it has an opening wide enough to allow the use of a flat brush. Evaporation may be prevented by inverting another jar of the same size over it. The shellac on the rim will hold them together practically airtight with the brush inside.

RELATIVE ADVANTAGES OF OIL AND WATER STAINS

The merits of these two classes of stains may be stated briefly. Water stains enter more deeply into the pores of the wood because of their lighter body. The hard parts of the surface hold practically none of the stain and constitute the high lights

of the finished surface. But water stains raise the grain and make sand-papering necessary to bring the surface flat again. For this reason, some polishers first give a coat of water to raise the grain and when dry sand-paper flat before staining.

Oil stains do not raise the grain, but owing to their heavier body do not penetrate so deeply and more of the stain is lost in rubbing off. Oil has a tendency to darken wood, so that wood stained with oil colours has a tendency to become clouded or muddy with age.

For staining old work, oil stains should be used rather than water stains. Old work has the pores already filled and water has little chance to penetrate.

Some chemicals and aniline dyes are very satisfactory. Bismarck brown, which may be bought at the chemist's as a powder, is soluble in alcohol and gives a rich reddish brown. It is very powerful and a very small quantity is necessary. Bichromate of potash comes in the form of lumps and crystals. It is soluble in water. Put half a dozen crystals in a quart milk bottle of water and allow it to stand over night. Warm or hot water will dissolve the crystals more quickly. It is to be put on with a brush and gives rich brown tints, the shade depending on its

strength, the kind of wood and the number of coats. It gives excellent results on oak and chestnut, and is used to "age" bay wood to a dark mahogany, while several coats of it will bring white wood to the colour of natural black walnut.

Each coat must be allowed to dry and then be rubbed flat with fine sand-paper.

This treatment may be followed by two or three coats of orange shellac, rubbed down.

For "antique" finish on oak or chestnut, dissolve lampblack in turpentine, mix with filler and proceed with polishing as explained.

A decoction of logwood is often used to produce dark and even black effects. The logwood extract is cheap and comes in the form of gum or resin. Several lumps of this are boiled in a gallon of water and applied as any water stain.

Acetate of iron, made from iron filings and vinegar, is used for dark browns occasionally. The filings should be allowed to stand for several days in the vinegar. The acid present is acetic. It unites with the iron forming the acetate of iron.

POLISHING

The method given above is for a substantial solid finish, but sometimes a boy will have some

difficulty in obtaining the desired finish through lack of patience or some other cause.

A French polish may help to give the finishing touch. For this a piece of cheese cloth about 6 inches square, a piece of cotton waste about the size of a walnut, a little shellac and raw linseed oil are necessary.

Dip the waste lightly in shellac; fold the cheese cloth around it, making a soft pad, dip the pad in the oil and rub quickly and constantly in circles, gradually covering the whole surface. As the shellac hardens or sticks, use a little more oil and squeeze the pad slightly to bring the shellac through the cheese cloth. The oil prevents the shellac from sticking and a little experience will give the right balance between the two. When the polish becomes so bright that it shows the slightest finger mark, wipe dry with a piece of soft flannel.

WAX POLISH

This is used where a dull or flat finish is required. It can be applied directly after staining or filling.

Dissolve beeswax in turpentine to the consistency of filler. Heat hastens this part of the process, but is not necessary unless time is a consideration. The wax is applied with a soft rag or waste and

rubbed and rubbed. The turpentine evaporates, leaving the wax. Several rubbings at intervals of a week will give the desired effect, and the surface may be brightened at any time by an additional application.

It should be remembered in all forms of polishing that dust is the great enemy. Wherever possible a piece of furniture after receiving a coat of shellac or varnish should be placed in a room or closet where no dust can settle on it. It should also be kept out of the sun to avoid blistering. The action of some stains like bichromate of potash is affected by the sun and should be either kept out of direct sunlight entirely or so placed that all parts receive the same amount, else the parts in shadow will be of a different shade from the rest of the surface.

UPLIFT VOCATIONAL SERIES

THINGS BOYS LIKE TO MAKE

PART II

ELECTRICITY AND ITS EVERY-DAY USES

BY PROF. JOHN F. WOODHULL, PH. D.

PREFACE

Why do we pursue one method when instructing an individual boy out of school, and a very different method when teaching a class of boys in school?

The school method of teaching the dynamo is to begin with the bar magnet and, through a series of thirty or forty lessons on fundamental principles, lead up to the dynamo, which is then presented, with considerable attention to detail, as a composite application of principles. This might be styled the synthetic method. He who teaches a boy out of school is pretty likely to reverse this order and pursue the analytic method. The class in school has very little influence in determining the order of procedure. The lone pupil with his questions almost wholly determines the order of procedure. Out of school no one has the courage to deny information to a hungry boy; in school we profess to put a ban upon information giving, and we do quite effectually deaden his sense of hunger. The school method rarely yields fruit which lasts beyond

the examination period; on the other hand, a considerable number of boys have become electrical experts without the aid of a school. This book is the story of how my boy and I studied *electricity* together. We have had no other method than to attack our problems directly, and *principles* have come in only when they were needed.

My boy had learned to read when very young by having stories read to him while he watched the printed pages. The construction of sentences out of words and words out of letters had come to him very incidentally but all in due time, and when he first went to school rather late in life for a beginner he found himself more proficient than the other boys of his own age both in reading and in understanding the printed pages. I could see no good reason why he should not pursue the same method in studying electricity.

We live in a modern apartment house in a great city. My boy likes to visit engine rooms and talk with the engineers about their machinery. His mother and I always encourage him to talk with us about the things in which he is most interested. If the family is alone at dinner, he is quite likely to lead the conversation into the field of electricity.

PREFACE

When particularly burdened with my work I have learned to find relief by giving an afternoon to Harold, who generally takes me to some electrical store or power station or to ride by electric train out into the country.

CONTENTS

ILLUSTRATIONS

ELECTRICITY AND ITS EVERY-DAY USES

I

THE DYNAMO AND THE POWER STATION

ONE day Harold expressed a desire to see the dynamos, five miles away, which furnish the electric light in our apartment. So I told him to invite his best friend to accompany us and we would go.

When we were some distance from the station the boys noticed the very tall chimneys and inquired why tall chimneys were needed for dynamos. I explained that the dynamos were run by steam-engines, and steam-engines required the burning of coal. "Oh!" said Ernest, Harold's friend, "I read in the paper that electricity is the rival of steam and is going to drive out the steam-engine." I suggested that we were about to see some steam-engines driving electricity out of that power station. But more seriously, I explained that steam-engines were used for many years as locomotives to draw the trains on the elevated railroads of New York City, and when at last they were displaced by electric trains some people thought that it was

a case of electricity driving out steam, whereas what had really happened was that the steam power for running those trains had been concentrated at a central station, and its power was merely transmitted to the trains by means of electricity. The trains were, therefore, run by steam power quite as much as ever. In like manner, the surface cars of New York a few years ago were run by a cable, which was merely a very long belt used to transmit to the cars the power of steam-engines located at a central station. When they were changed to electric cars, electricity became the successful rival of nothing else than a twisted wire cable. The cars still run by steam power as before, but that power is transmitted by electricity instead of the discarded cable. Steam has driven out the horse as a power for drawing street cars, and electricity has enabled us to gather all the steam engines into central stations, where now they are furnishing the power for moving surface, elevated, and subway cars for street traffic, as also trains for suburban travel. Central station steam-engines are producing a vast amount of power, distributed all over the city by means of electricity, for doing a great variety of work and for furnishing electric

light and heat, all of which we shall presently study. "Just before we go into this central station, can you tell me how the elevator is run in our apartment house?" "It is an electric elevator," said Harold. "And where does the electricity come from?" I inquired. "Well, I know that it comes from the street mains, but do they come from this power station?" "Yes," said I, "and we will now go in and see the steam-engines which lift you up stairs many times each day by sending electricity to run that elevator. If you choose to do so, you may claim for purposes of discussion that your elevator is run by steam."

As we entered the building we came first to the dynamo room and both boys noticed that the tone which met their ears was that which I had produced for them in the telephone the night before. "I shall try to show you before we get through," I said, "that these dynamos are doing something which makes iron pulsate sixty times a second and that that is the cause of the pitch of this tone. But let us begin with the coal which is the source of all this power.

"This particular station at the present time is burning forty tons of coal an hour. That is as much as Mr. —— uses to heat his twelve-room

house for a whole year. One pound of coal is capable of liberating enough energy to supply $5\frac{3}{4}$ horse-power for an hour. (Written for short $5\frac{3}{4}$ H.P.H.) One ton of coal is capable of furnishing ($2,000 \times 5\frac{3}{4}$) 11,500 H.P.H. Forty tons would yield 460,000 H.P.H. But the best furnaces, boilers, and steam-engines are terribly wasteful of energy. About nine tenths of all this energy is wasted and only one tenth, or about 46,000 horse-power per hour, is delivered by the steam-engines to the dynamos.

"Coal is already scarce in the world and the supply is rapidly being exhausted. Meanwhile we are growing more dependent upon coal. A century ago we used scarcely any power except that of men, horses, and oxen, and what little heat men then used came chiefly from wood. They lived in cold houses, attended cold churches and schools, did not ride in steam or electric cars, and did not have power plants. Our wood is nearly all gone, our coal is going, and we are very rapidly growing more dependent upon heat and power, our chief source of which is coal. Wind power is too uncertain to depend upon, and we turned our backs upon water-power when we began to crowd into cities. What little

water-power there is, however, is nearly all in use.

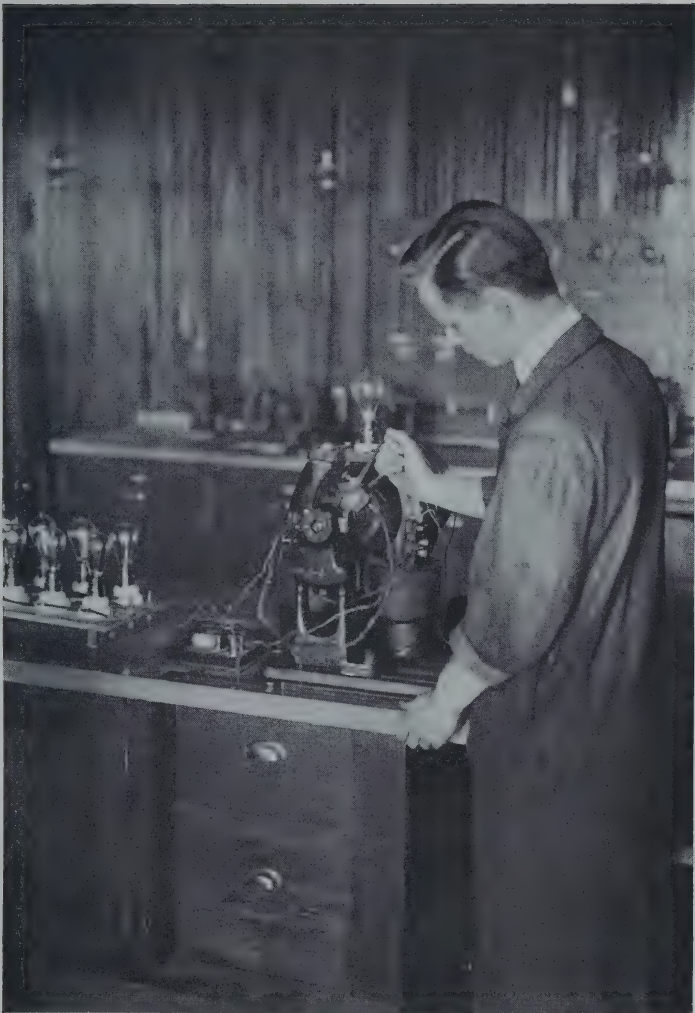
"There is great need both that we learn how to save the major part of the energy of the coal which we now waste, and that we find a substitute for the coal to use when that is gone.

"A part of the heat from the forty tons of coal which is being burned in this particular power plant goes into the water in the boilers. It converts this water into steam. The steam, if free to expand into the air, would occupy about one thousand seven hundred times the volume of the water. We compel it to expand through the cylinders of the steam-engine, using its force of expansion to make wheels go around — to make the dynamo revolve. These dynamos are not *devices for producing power but merely for transmitting* the power of these steam-engines to far away places where it may be used, as, for instance, in our apartment house, where we are unwilling to walk upstairs and want some power to carry us.

"Our own apartment is fifty feet above the street. I weigh one hundred and sixty-five pounds. If I walk up stairs from the street to our apartment in one minute, which is the rate of a rather slow elevator, I work at the rate of one quarter of a horse-power.

One hundred and sixty-five pounds raised two hundred feet in one minute requires one horse-power. You boys each weigh about half as much as I do, and if one of you walks up the same stairs in one minute you exert half the power that I do, or if you run up the stairs in half a minute you exert the same power, that is, one quarter of a horse-power. When we three walk up together in one minute we exert one half horse-power. If we all three run up the stairs in half a minute we expend one horse-power. Now, the speed of elevators for apartment houses is about one hundred feet a minute. We are unwilling to walk up stairs, not because we are lazy but because we have the New York haste, and so we employ elevators which run at the rate of about one hundred feet a minute.

"These dynamos enable us to employ the power of this central station to run the elevator in our apartment house. Here is a dynamo rolling over now in the act of sending out power, some of which goes to that elevator; and standing beside it is another waiting to be used when necessary. Examining these dynamos, we find that they are composed of nothing else than iron and copper. About all that we can say of these mysterious



Photograph by Helen W. Cooke

Testing a Generator

machines is that the moving iron generates the electricity and the copper leads it away.

"Each one of these dynamos has many hundred tons of iron in it. A huge wheel of iron, thirty-two feet in diameter, one hundred feet in circumference, portions of which are surrounded by insulated copper conductors, forms the centre-piece of the machine. This movable part weighs

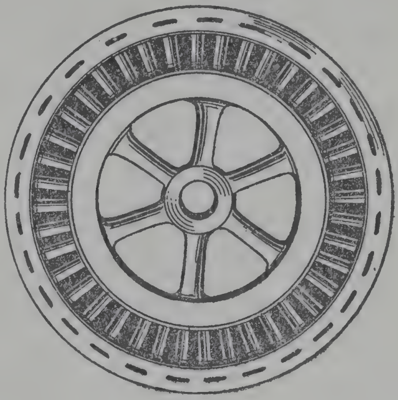


Fig. 1

four hundred tons. Around about this is a fixed ring of iron, portions of which are surrounded by insulated copper conductors. Ordinarily the ring which is stationary is called 'the field,' and the wheel, which rotates, is called 'the armature,' although these terms are sometimes reversed for certain reasons. The movable part in these machines rotates about once a second, that is, its circumference moves a little faster than a mile a minute. The iron moving at this high rate of speed creates ether streams or electric currents, which are led off by the copper con-

ductors. The generation of electricity on a large scale requires large masses of iron and high velocity."

I noticed that the boys stood before this machine in a state of utter bewilderment, bewildered as a man who is told that what he had considered north is really south, bewildered as a man who, having wandered through a maze of city streets, looks up at length and unexpectedly finds the building he has been seeking towering before him. The questions they asked were entirely without thought. "What is inside of it?" "Simply more iron and copper, such as you see on the surface," I replied. "But what makes it go?" "The steam-engines, of course, four of which you see, are coupled directly to each dynamo." "But where does it get its electricity?" "Don't forget that you are looking at *a generator* of electricity. Big mass of iron — rapid motion! That is the whole truth. But it cannot satisfy you as an answer until you have become used to it. We have seen all that we ought to see here to-day. Let us drop the whole matter now, but return to my laboratory to-morrow, and I will give you the next step which will help you."

The boys did no talking upon their return journey. Whether one may say they were thinking or not I cannot tell, but certainly their ideas were incubating.

II

THE DYNAMO, CONTINUED — THE MAGNET

WHEN we had gathered at my laboratory the next day I took down a spool of one pound No. 24 cotton-covered copper wire (Fig. 2 *A*), which had its centre filled with wire nails. The boys had seen it before and remembered it. With flexible wires I connected the two ends of the wire on this spool to a sensitive ammeter, *B*, which had its zero in the middle of the scale, and I laid down upon the table a bar magnet, *C*.

"Here," I said, "is a dynamo complete. The bar magnet furnishes the 'field' and this spool of copper wire, *A*, which I will move back and forth immediately over the magnet from end to end, is 'the armature.' *D* and *e* are the line wires and the circuit is completed through the ammeter to show whether we are generating electricity. And now as I move this armature along the field you see the needle of the ammeter move to the right from zero to ten. When the armature is moved in the opposite direction along the field the needle moves

in the opposite direction past zero and on to ten at the left. The moving of the needle in the ammeter shows that we are generating electricity. The swinging to and fro of the needle shows that we are generating an alternating current of electricity. It is a mere matter of detail whether we move the armature or the field, as I will show you by letting the spool *A* rest quietly upon the table and moving the mag-

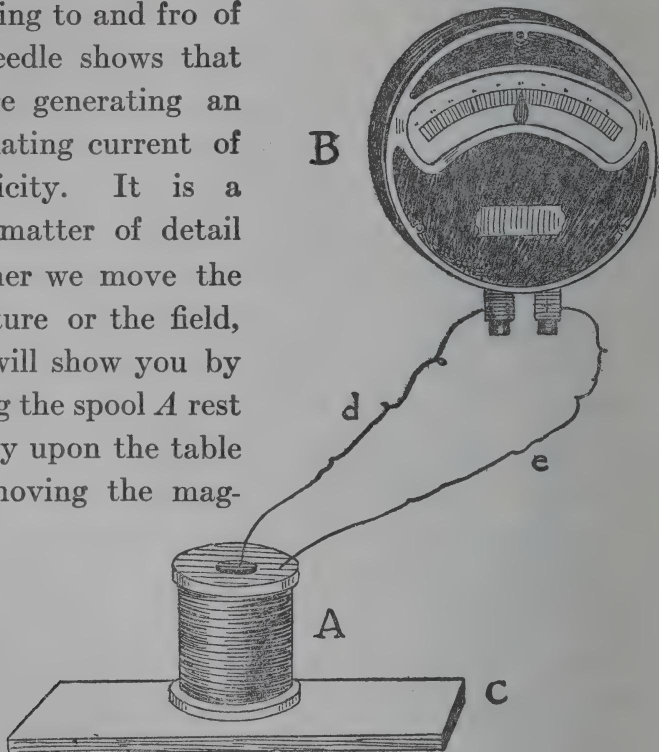


Fig. 2

net to and fro lengthwise across the end of the spool. Or I may accomplish the same results by moving them both in opposite directions. It is simply necessary that they move *with reference*

to each other. Some dynamos are made with stationary fields and rotating armatures, some with stationary armature and rotating fields, and some with both parts designed to rotate in opposite directions.

"Magnetism is not confined to the magnet. It extends more or less widely into the region about it. It is this region affected by the magnet that we designate its magnetic field. By bringing this sensitive compass needle into the region of this bar magnet from all directions, I show you that it has a slight power to change the direction of the needle when about a foot away. This power grows rapidly greater as the distance grows less. Of course its field extends rather indefinitely, but we may say that this particular magnet has an appreciable field extending about one foot in all directions from it. We find upon examination that some magnets have bigger and stronger fields than others, that all have their strongest fields when first magnetized and lose their strength gradually, *but never entirely.* We find that hardened iron and steel hold magnetism longer than soft iron, *but all iron is magnetized somewhat at all times.* Iron that is feebly magnetized can be made into a strong magnet by bringing it into a strong magnetic field.

The earth is a feeble magnet, and that is why it gives direction to the compass needle. That is also probably the reason why every piece of iron upon the earth is a magnet, or, to put the cause back another step, we may say that whatever causes the earth to be a magnet also causes every piece of iron upon the earth to be likewise a magnet.

"But thanks to Oersted in Denmark in 1819 and Faraday in England in 1821 and Joseph Henry in Albany, N. Y., in 1827, we have learned to make exceedingly powerful magnets by sending a current of electricity in a whirl around the iron. This is the meaning of the coils of copper wire around iron cores in the dynamo, in electric bells, in telegraph sounders, in motors, etc., etc. To prevent the electric current from taking the shortest route, through the iron core or through the successive layers of copper wire, the iron core and the wire must be covered with something like wood or paper or cotton or silk or rubber — such things as electricity does not readily pass through — that is, insulating material.

"Joseph Henry, while teaching in the Albany Academy, was the first to make electro-magnets. There was no such thing as wire covered with an insulating material then in the market, and he wound

all his wire with silk ribbon. But in the year 1834 he made magnets which lifted thirty-five hundred pounds, to the astonishment of every one. A pair

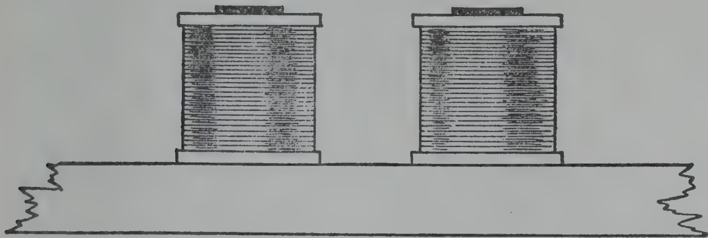


Fig. 3

of such electro-magnets as I have here (Fig. 3), each consisting of one pound of No. 24 cotton covered copper wire, eight hundred feet long, wound in one thousand turns about an iron core two inches in diameter, will lift several hundred pounds: much more than we three can lift, as I shall now show you."

The cores of the two magnets were bolted fast to an iron beam, and a large bar of iron with a ring in it was laid across the other free ends of the magnet cores. I made connections with the electric lighting circuit (that in my laboratory is what is called a direct current), and sent a current of electricity around the coils. The two boys and I tugged at the ring in the iron bar to no avail. We were unable to pull the iron bar away from the mag-

net. But when I opened the switch and cut off the electric current, one boy with one finger in the ring lifted the bar with perfect ease.

"Electro-magnets are now made with a magnetic intensity 90,700 times that of the earth's magnetism. Electro-magnets are used for hoisting iron castings weighing many tons. Here is a picture of an electro-magnet lifting a whole wagon load of kegs of nails from the wagon to the hold of a ship.

"Electro-magnets are our only means of utilizing electricity for power. It is the pull of electro-magnets that moves the electric car. Electro-magnets are now used for pulling all the trains out of the Grand Central Depot in New York City.

"Let us now compare the strength of our electro-magnet with that of the bar magnet used in our former experiment."

I opened and closed the switch, which sent the electric current through my magnet coils at frequent intervals, and the two boys, each with a compass needle, searched the field for magnetic effects. They found that the magnetic field extended six or eight feet, but this piece of research was broken up by a new idea which appeared to strike them both at the same instant, for they shouted both together,

Photograph by Helen W. Cooke

Wiring

"Let's use this electro-magnet in place of the bar magnet for our dynamo experiment!"

"That is surely the next step in our programme," said I, "but you will need a steam-engine to move an armature in this magnetic field, will you not, judging from the struggle we had with that iron bar a few minutes ago?" The boys looked quite hopeless until I said, "The best thing about the electro-magnet remains yet to be told. You have perfect control of its strength by changing the amount of electricity which you send around the coil.

"By means of an instrument which works like the motorman's controller on the electric car, I may control the amount of electricity which flows, just as well as you may control the flow of water by a faucet or stop cock. By this means I will control the strength of the magnet so that you may move the armature in your dynamo experiment.

"In 1821, Faraday, at the Royal Institution, London, learned that he could produce magnetism by means of the electric current, and, in 1831, he learned that the reverse was also true, namely, that he could produce electricity from magnetism. This idea coming as the result of ten years of incessant search made him shout and dance like a child. You are feeling a little of the pleasure of his discovery."

I then fastened one of the coils upon the table underneath a small bench (Fig. 4) and sent an electric current around it. The other coil, *B*,

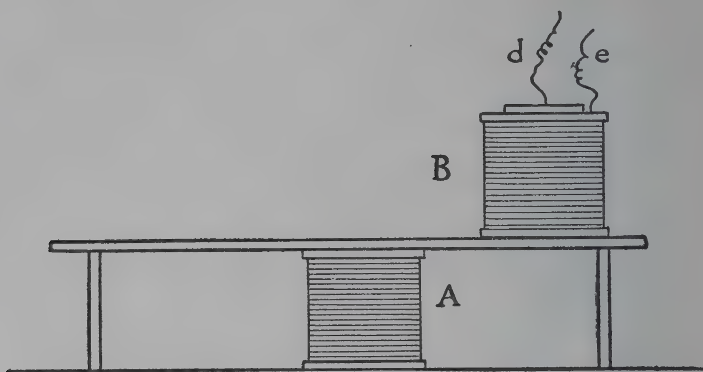


Fig. 4

connected with the ammeter was pushed back and forth along the surface of the bench over this coil. The boys found that the more electric current I sent around the coil *A*, that is, the stronger I made the magnetic field, the harder it was to move the coil *B*. They found that the nearer *B* was to *A* the harder it was to move it. They found that the faster they moved *B* the more electricity was produced. They tried laying *B* upon its side upon the bench and thus moving it. They tried taking *B* off the bench and moving it on all sides of *A*. They found it much harder to move in some ways

than in others, but in all cases they found that the harder they had to work the more electricity was developed, as was shown by the ammeter.

"The dynamo is any machine which will convert mechanical work into electricity. The magneto is one form of a dynamo which you have used much at the summer cottage, but have never seen the inside of. Here are several (see Figs. 5, 6, and 8) which I will let you examine inside and out, and with these I must leave you to yourselves for a time."

When I returned I asked the boys why these dynamos were called *magnetos*. "Because they have steel magnets for their fields," they replied. "There are several magnets bent in the shape of a horseshoe."

"Yes," I said, "in this case the field is made stronger by taking several magnets. Have you noticed any armature?" "Yes, it is made of iron with insulated copper wire wound around it."

"Please recall that the amount of energy you expend in going upstairs depends on two things: (1) your weight and (2) the speed with which you move. Also recall that the amount of electricity you could generate with a dynamo depended upon the amount of energy you expended. Therefore,

the strength of the electric current which this machine may produce depends upon two things: (1) the strength of the magnetic field against which you must pull and (2) the speed of the motion of the armature. Evidently this field is made as strong as it is possible to make it with steel magnets. Now is there any device for giving high speed to the armature?"

"Yes, indeed," said the boys, "one has a pulley so that it may be connected by a belt with a gas-engine, and the others have each a large cog-wheel working into a smaller one. We found in one of them that a single revolution of the crank gave six revolutions to the armature."

I found that the boys had made large-sized drawings of the parts, and were preparing to report on the magneto as a form of dynamo at the next meeting of the Science Club, which we had started among the boys in school.

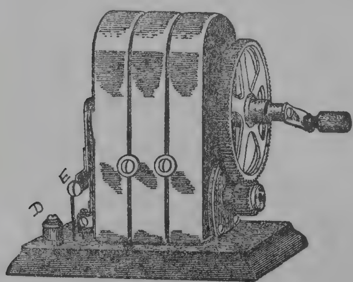


Fig. 5

"I will loan you some apparatus so that you may give a very interesting demonstration on that subject," said I, "only let me show you how to use

it first. Connect the binding posts *D* and *E* of this magneto (Fig. 5) with my ammeter. Turn the crank *very* slowly and notice that the needle of the ammeter swings to and fro with each revolution of the armature. That shows that you have not only a *dynamo*, but an *alternating current* dynamo.

"Now connect the binding posts *d* and *e* of this magneto (Fig. 6) with a short piece of copper wire. Turn the crank and you notice that this dynamo rings two electric bells. Turn slowly and you notice that the alternations of the current are numbered by the strokes on the bells. The hammer swings to and fro just as the needle of the ammeter did.

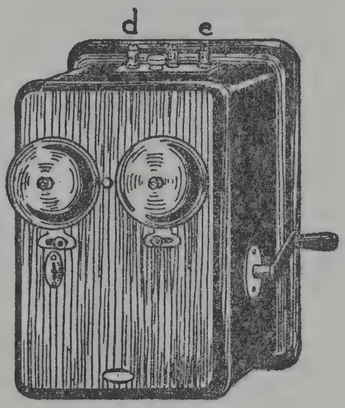


Fig. 6

Each bell therefore receives one stroke of the hammer for each revolution of the armature. Now try to turn the crank steadily at the rate of one revolution per second. The armature is making six revolutions, or cycles, per second and you now have not only an alternating current dynamo but a *six-cycle alternating current dynamo.*

The lighting circuit used in our apartment is a *sixty*-cycle alternating current. To be sure the armature of the dynamo which generates that current revolves only once a second, but it carries coils enough upon its rim to make that number of alternations.

"Now connect this telephone receiver with the binding posts *D* and *E* of this magneto (Fig. 7). Unscrew the cap of the receiver. Move to one side the iron diaphragm and turn slowly the crank of the magneto. Notice that the diaphragm vibrates in time with the alternations of the dynamo. Replace the diaphragm, screw on the cap, hold the receiver to your ear and turn the crank as fast as you can. You will probably be able to make about sixteen cycles per second. The receiver in that case is giving forth a sound of the same pitch as a sixteen-foot closed organ-pipe.

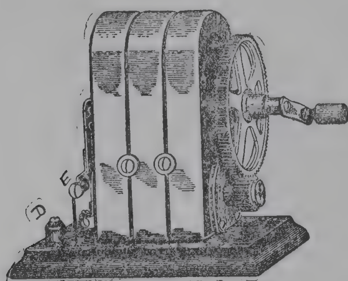


Fig. 7

"Connect the telephone receiver to the binding posts *D* and *E* of this magneto (Fig. 8), and by means of a belt connect the pulley to this series of cog-wheels. Now you may turn the crank and readily make the

armature revolve at the rate of sixty cycles per second, and you notice that you get the same tone that we heard in the dynamo room of the power station and the same tone the telephone receiver gave when I connected it to a coil in our apartment. The tone which is produced by sixty vibrations per second is very nearly that of the C two octaves below middle C on the piano. Try it along with the piano and you will find it a little flat. This string on the piano is making sixty-four *vibrations per second.*

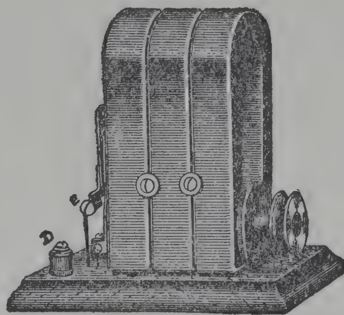


Fig. 8

"Now connect this miniature telephone switchboard lamp with the magneto (Fig. 9) and turn the crank fast. The lamp lights up to full brilliancy and you notice that the light is steady, although it is made by an alternating current passing through the filament in one direction, stopping entirely,

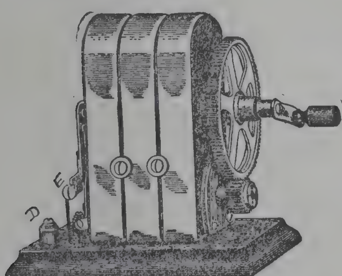


Fig. 9

and then passing in the opposite direction. The filament has no time to cool off, provided you turn fast enough, but try turning a little slower and you will notice the flickering of the lamp."

III

THE AMMETER

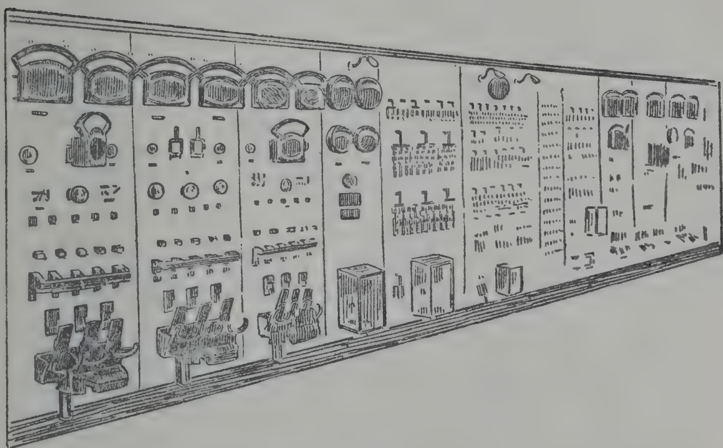


Fig. 10

AT THE last meeting of the Science Club so many questions were asked, which the demonstrators could not answer, that a programme committee, to whom such questions might be referred thereafter, was appointed. It was made the duty of this committee to assign to various members the task of searching for satisfactory answers, and when the material was ready

to be reported to the club, the programme committee determined the time and order of presentation. I found that I had been made an honorary member of this committee and that it was expected that I should steer the committee. I told them that I accepted this appointment with the understanding that the fellow who steers is always the smallest man in the crew, and if they would do all the work I would enjoy the honorary title of cockswain. Secretly, however, I appreciated that this was in effect adding several courses to my already rather heavy programme. I must, under the régime, direct a large number of inexperienced students in library research, in laboratory research, and in the art of giving demonstrations with apparatus and experiments to audiences.

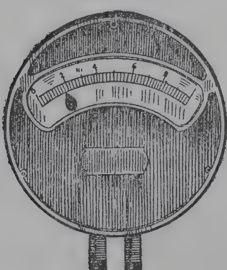


Fig. 11

The most urgent questions, as also those which were next in the natural order, concerned the *ammeter*. I told the committee to make that the subject of the next meeting and to send to my laboratory on a certain day the person or persons whom they might appoint to report upon it.

I find that the boys never come singly, but gen-

erally in pairs. When the boys came they found lying upon the table an ammeter (Fig. 11).

I told one of them to take out the three screws in the front and remove the face of the instrument. I had told the boys that the instrument cost sixty dollars and that letting them open it was like letting them open my watch. As soon as the face came off one of the boys exclaimed that from my reference to the watch he had expected to see very complicated machinery with many wheels, but from the exceeding simplicity of the mechanism he could not see why it should cost sixty dollars. I told him that although it was a fine piece of workmanship it was fortunately very easy to understand, and I asked them if it reminded them of anything else that they had ever seen. After a few moments of reflection they agreed that it was very much like one of the magnetos. "Well," said I, "where is the field?"

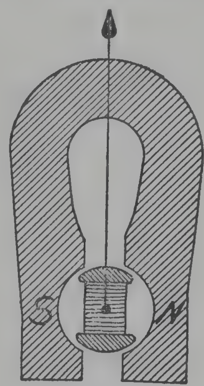


Fig. 12

"Is this horseshoe arrangement a magnet?" they inquired.

"There is a compass needle right at your hand waiting to answer that question," I replied. They

immediately found that it was a magnet. "Well," I said, "to be really sure that it is a magnet you must find a portion of it that will *repel* a portion of your compass needle as well as other portions in both horseshoe and needles which attract each other." Whereupon, they found that the portion marked *N* (Fig. 13) repelled the blue end of the compass needle and attracted strongly the bright end of the needle, while the portion marked *S* did the reverse. We will call *N* and *S* the poles of the magnet. This is simply a steel bar magnet bent into the shape of a horseshoe."

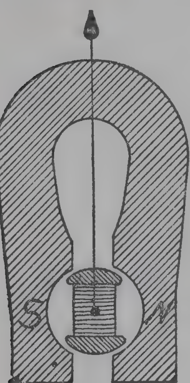


Fig. 13

"You told us," remarked one of the boys, "that steel magnets gradually lose their strength. How then can this be correct as a measuring instrument?"

"It is the purpose of the iron case to enable this magnet to retain its magnetism, and if you will examine its field, as we did that of another magnet upon a former occasion, you will find that although this is a strong steel magnet its field does not extend outside of the iron case. It is as though we could box up magnetism and keep it from escaping.

"Now if this is like the magneto, where is the armature? The spool-like thing between the poles of the magnet looks just like the armature in one of the magnetos.

"Yes, it has an iron core with a coil of insulated wire around it, and you remember that when an electric current is sent around a piece of iron, that iron is made into a magnet, and if it is a magnet it must have poles. It is very delicately poised upon a pivot and will act exactly like your compass needle, which is also a little magnet with poles. I will send an electric current through the wire which surrounds this armature, and you notice that the needle which it carries moves to the right. Notice that the lower end of this armature acts like the blue end of your compass needle in that it is repelled from the pole *N* of the field and is attracted toward *S* of the field. In like manner, the upper end or pole of the armature is repelled from *S* and attracted to *N* of the field. The blue end of the compass needle is called its north pole because it points north under the magnetic influence of the earth, and so we may call the lower end of the armature its north pole.

"The electric current which I am sending through the armature comes first through one ordinary

16-candle-power electric lamp which you see lighted on this 'resistance board,' as it is called, and you notice that the needle points to .5. This means that half an ampere of electricity is passing through this lamp. I will now send the current through a 32-candle-power lamp, and you notice that the needle points to one, indicating that one ampere is required to light that lamp. But what prevents the needle from going farther, and what brings it back to zero each time?" The boys discovered a very small spring, like the hair spring of a watch, coiled around the pivot of the armature. "So, then, one ampere of electricity gives magnetism to this armature so that it may pull against its coiled spring hard enough to carry the needle to the point one. Twice as much electricity will give it magnetism enough to carry it to two, and so on across the scale.

"The full name of this instrument is Ampere meter, which by usage has been shortened to ammeter. It was named in honour of André Marie Ampère, who was born at Lyons, in France, in 1775, the year our Revolutionary War broke out. He died in 1836. When Oersted made his famous discovery of the action of an electric current upon a magnetic needle, in 1819, Ampère was in middle life (forty-four), and took up the same line of research with

great vigour. The next year, 1820, he discovered what you will doubtless enjoy rediscovering now.

"You will notice that the binding posts on the bottom of this ammeter are marked, one positive, +, and the other, negative —. The electric current now enters the instrument by the post marked + and after passing around the armature leaves by the post marked —. I will reverse the connections and thus send the current around the armature in the other direction, and you notice that its poles are now reversed. The lower end which was formerly the north pole of the armature has now become the south pole, as proven by the fact that it is repelled from the south pole of the field and attracted to its north pole. This carried the needle to the left, and inasmuch as the zero is in the middle of the scale we may with this instrument both measure the amount of current and tell its direction. You will recall that when we connected the magneto with this intrument, it indicated that the magneto sent the current first in one direction and then in the other, which we call an 'alternating current.' But you notice that the current which I am using in this laboratory flows continuously in one direction. This is called the 'direct current.' We shall find out how a dynamo may produce a direct current

at another time. Let us not forget, however, that we have repeated Ampère's discovery, and found out that the direction in which we send the current around an electro-magnet determines which end shall be its north and which its south pole. If you will note carefully which way the wire is wound around the armature you will see that when I send the current in at the positive post it is passing around the north pole of the armature opposite to the direction in which the hands of a clock move. If I reverse the current it passes around the lower end of the armature *in the same direction as the hands of a clock move* and then this end becomes a south pole. This is 'Ampère's rule,' and it is what candidates for admission to college are very careful to learn.

"Before we replace the face of this ammeter I must call your attention to a wire running by a short cut from one binding post to the other, *s* (Fig. 14). Suppose *a* represents the wire around the armature. Electricity, like water, goes more readily through a big conductor than a small one and more readily through a short than a long conductor. If *s* and *a* were water pipes, each having a stop-cock, we might easily adjust the cocks so that one tenth of the water would go through *a* and nine tenths through *s*. Or, indeed, without stop-

cocks, the size and length of *s* and *a* might be so apportioned that one tenth of the water would flow through *a* and nine tenths through *s*. This is precisely the adjustment which has been made with reference to the flow of electricity through this instrument. *s* is called a 'shunt.' When the shunt is out all the current goes through *a* and when the shunt is in only one tenth of the current goes through *a*. I have two other shunts, each of which may be put in the place of *s*.

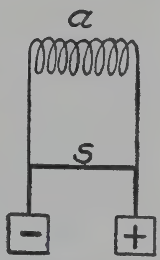


Fig. 14

With the second only one hundredth of the current goes through *a* and with the third only one thousandth of the current goes through *a*. Thus I have an instrument which will measure anything from one thousandth of an ampere up to ten amperes.

"In this laboratory we pay about one cent for an ampere of electricity for one hour. Twice as much coal must be consumed to furnish two amperes as one, and twice as much coal must be consumed to furnish an ampere for two hours as for one hour. Hence we need an instrument which will keep account of time as well as amount of current. Such an instrument we must look into next.

"Just before we pass to that, however, let me ask if you have ever heard of a 'shunt-wound' dynamo. Can you guess from the way we have just used the word 'shunt' what the expression could mean with reference to a dynamo?" Without hesitation the boys told me that it meant that the field and armature were wound parallel to one another, as shown by diagram in Fig. 15. In which case the electric

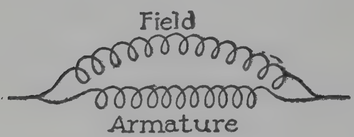


Fig. 15

current which the machine generates divides, part of it going around the field and part around the armature. Another type, called series-wound dynamos, is indicated by diagram in Fig. 16, in which case the electric current goes through field and armature in succession. Under either of these circumstances, how can the armature move with reference to the field? The answer will appear in the next chapter.

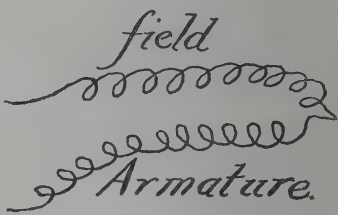


Fig. 16

IV

THE WATTMETER

WE WERE able to mantain connections between the binding posts of the ammeter and the movable armature of flexible wires because the armature never moves more than one third of a revolution, but we now wish to examine an instrument in which the armature must not only make a complete revolution but must continue to revolve in the same direction indefinitely. How are connections made so that an electric current may pass from the fixed binding posts to the wire of the moving coil? I will lift the cover off this instrument, which is called a wattmeter, and let you find the answer to that question.

I sent through the instrument the current from a 32-candle-power lamp. According to the ammeter, which was also in circuit, the amount was one ampere.

The armature of the wattmeter revolved slowly and it was not long before the boys reported that connections for the current were made by strips of

metal sliding on metal plates. The ends of the armature wire were fastened one to one plate and the other to the other plate, and the metal strips brush along over the surfaces of the plates. (That is why they are called "brushes," I said.) And the brushes slide from one plate to the other each time the armature makes half a revolution. (That is, the brushes change the connection and thus change the poles of the armature at the proper instant so that they are always attracted to the poles of the field toward which they are moving.) This is called a commutator.

Notice that while the ammeter was like the magneto in having a steel magnet for its field, the wattmeter is like the dynamo in having electromagnets for both armature and field. Notice in the second place that this instrument is an *electric motor* since it is made to revolve by an electric current. If it were made to revolve by some other power it would generate electricity and would then be called a dynamo. Indeed, let me tell you something which must at present be nothing more than a puzzle to you. *Every machine, while it is being driven by an electric current as an electric motor, is, at the same time, acting as a dynamo to generate a current in the opposite direction.* Notice

in the third place that this is a shunt-wound instrument. The current which is sent into the instrument divides, and part of it goes through the field, while part goes through the armature. Motors, as well as dynamos, are either shunt-wound or series-wound. But notice finally that the axle on which the armature is carried has a cyclometer arrangement which keeps account of the number of revolutions. The armature is going slowly enough for us to count the revolutions. With watch in hand we found that it made one hundred and twenty revolutions per minute. I next brought the current to the wattmeter through a 16-candle-power lamp and the ammeter, connected in series, showed that half an ampere was passing. We counted the revolutions of the wattmeter and found them to be sixty per minute.

Here, then, is a simple electric motor which will register the amount of electricity we use. It will register the same amount whether we use one ampere for one hour or half an ampere for two hours or two amperes for half an hour. In any case this product is called *one ampere hour*. But the words printed upon the dials of this instrument are not *ampere hours*, but *watt hours* and the name of the instrument is *wattmeter*. This next requires

explanation. Follow me in a little roundabout journey and the matter will be readily understood when viewed from another approach.

When we were estimating the energy required to climb the stairs of an apartment house, we needed to take into account two factors, (1) our weight and (2) the time which we took in climbing them. The amount of coal burned, steam generated, electricity produced, to run our elevator depends upon two factors, (1) its weight and (2) its speed. That idea is fundamental. Let us get at it in still another way. Suppose we have a mill pond, (Fig. 17, *A*). We construct a penstock *p* and install a water-wheel, *S*, to operate a mill. Our business increases and we install more machinery in our mill and must have more power to run it. We have two ways of getting it, (1) we may lengthen our wheel and enlarge our penstock so that a greater weight of water will fall upon the wheel, or (2) we may lengthen our penstock and move the wheel

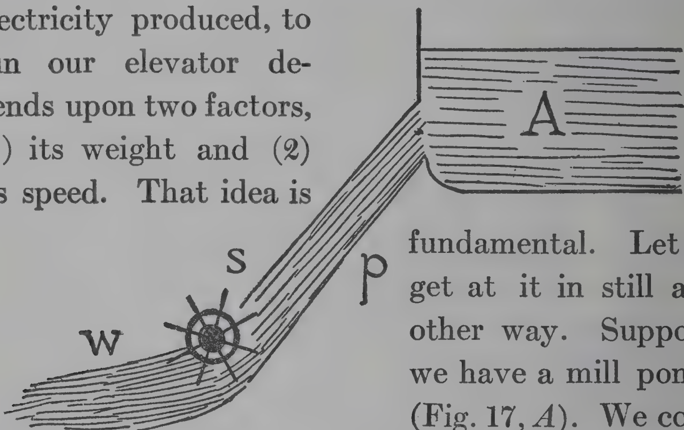


Fig. 17

farther down so that the water will fall upon the wheel with greater velocity. It is just so with the electric current. Like water it is driven on in its course by pressure. The unit for electric pressure is called a volt. If we wish to drive the wattmeter or any other electric motor twice as fast as now, we may choose whether we shall do so by doubling the volts of pressure or by doubling the amperes of quantity.

The electric pressure on our mains is about one-hundred and ten volts. We three together weigh 330 pounds. Our elevator brought us up stairs at the speed of 100 feet per minute. It requires one horse-power to raise 330 pounds 100 feet in a minute. The ammeter in the engine room showed that 7 amperes of electricity were sent through the motor of the elevator to bring us up. That is, seven amperes at 110-volt pressure give one horse-power. In the office building across the street where they use a 220-volt current 3½ amperes are required to take us up stairs at the same speed. It is necessary that the same amount of coal be consumed to furnish the horse-power of energy whether we supply it by means of seven amperes at 110 volts or 3½ amperes at 220 volts. You notice that the product is 770 in each case. The name given

to this product is *watts*. More accurately 746 watts of electrical power are equivalent to one horse-power. The name of this unit commemorates the famous inventor of the steam engine, James Watt (1736–1819). His monument now overlooks the Clyde at his native town, Greenock, Scotland.

To light a certain lamp, to heat a certain laundry iron, to furnish a certain amount of power for an electric motor, we must have a definite number of watts. We may choose whether we will have it at high or low voltage with correspondingly low or high number of amperes.

We will now connect with our laboratory current a 32-candle-power lamp, an ammeter, and a wattmeter, all in series, Fig. 18, and in parallel with

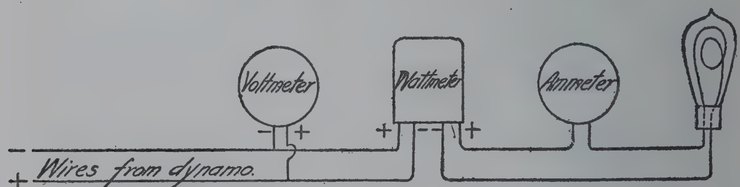


Fig. 18

these a volt meter. This last instrument indicates the electric pressure. Its mechanism will be examined later. The volt meter indicates 110 volts and the ammeter shows that one ampere is passing.

Photograph by Helen W. Cooke

Watt Meter

The filament in the lamp resists the passage of the current. It gets quite hot and gives forth as much light as thirty-two candles. Its resistance is just such that 110 volts of pressure send one ampere through it. We will now take the reading of the wattmeter, note the time and read it again later. One hour later its index showed that 110 watt hours of electrical energy had been converted into light and heat. This at the usual rate, costs 1.1 cents, one cent per hundred watt hours or ten cents per thousand watt hours, called a kilowatt hour. The more common 16-candle-power lamp costs about half a cent an hour to operate. It requires one horse-power to keep fourteen of them burning.

I will now take you to see the wattmeter which measures all the electric energy used in this building. You note down its reading and the date and the next time you come we will read it again and thus find out how much electricity has been used for electric lights, for electric ventilating fans, for electric elevators, for electric ovens, and electric irons in the school of household arts, for electric motors to run lathes and other machines in the school of technical arts, for electric experiments in my laboratories and lecture room, for

electric vacuum cleaners and, lastly, for pumping the pipe organ in chapel.

I saw by the boys' faces as they departed what would be the next question that they would bring to me. Knowing, however, that the hour was up, they were too polite to press it then.

V

THE ELECTRIC MOTOR

IN a few days I received a telephone message, asking if I could appoint an hour to meet the programme committee in my laboratory. I must confess that my pleasure in these meetings had increased so much that I was quite ready to slight other duties, if need be, to engage in them. Moreover, since my business was education it was not difficult for me to regard these meetings in the light of a duty quite as important as my regular class instruction— perhaps more effective. At any rate the boys and I managed to get together. May God forgive the man who essays to teach boys, but does not love to be with them.

Of course at the last meeting of the Science Club every one wanted to know how we ran a pipe organ by electricity. Moreover the Electrical Show was coming on in the city, and cows were to be milked by electricity, dishes were to be washed by electricity, rugs and furniture were to be cleaned

by electricity, and innumerable distracting and distressing things were to take place. I told the boys that really only two kinds of things were to be done by electricity at the show, and if they would give me two one-hour appointments I would furnish them with the key to the whole show. We might as well begin to-day with the pipe organ question.

A pipe organ is operated by air. It has bellows which are simply one form of an air pump. A boy is often employed to turn a crank which works the bellows. Down in the basement underneath our pipe organ I will show you how a half-horse-power electric motor takes the place of a boy. We found a dark and dirty corner where a boy used to stand and turn a crank every time æsthetically inclined people enjoyed an organ recital in the room above. Science, which has not been given credit for being *humanitarian*, put an electric motor into that dark corner and sent the boy up stairs to hear the music. The motor *grumbled* at the dirt in the corner and compelled the janitor to keep it clean.

The electric motor, better than any device I know, enforces justice, but never requires mercy, or at least rarely receives it. It comes nearer

than any other machine to paying back all that you put into it. It is most economical when working up to its full capacity. I recommend that you look it over carefully and after a few minutes tell me what you have seen in it.

The boys said that it looked just like a dynamo. We must not forget that it is a dynamo, but is here used as a motor by sending an electric current through it. This fact, that a dynamo might be driven by an electric current and serve as a mover of other machinery, was first publicly exhibited in 1873 at the Vienna Exhibition, and by many believed to have been discovered by accident at that exhibit. But why does it look like a dynamo? It has a field whose magnetism is produced by an electric current sent through coils of wire, and it has an armature whose magnetism is likewise produced by the electric current. If it were used as a dynamo, where would it get the electric current to magnetize its field? From its own moving armature. Is it adapted for direct current? Yes.

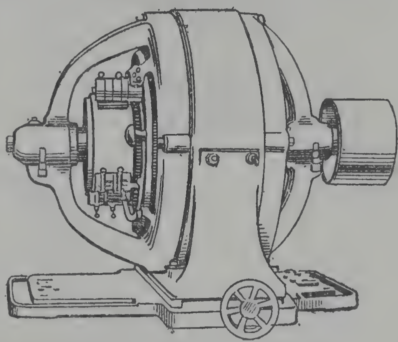


Fig. 19

It has a commutator and brushes. Is it shunt- or series-wound? Shunt-wound, as shown by diagram in Fig. 20.

Suppose we treat the machine as a dynamo. Bring the ends of the line wire together, thus, as we say, closing the circuit. By some external force let us cause the armature to rotate and under the influence of the magnetic field it will generate an electric current, part of which will pass through the field and part through the line circuit. We may adjust the relative amount of wire in field and line so that any portion of the current we choose will pass through the field. The amount of current it will generate depends, (1) upon the strength of the field and (2) upon the speed of the armature. Its field, although never entirely without magnetism, is very feeble at first, and hence in the first instance a very small current

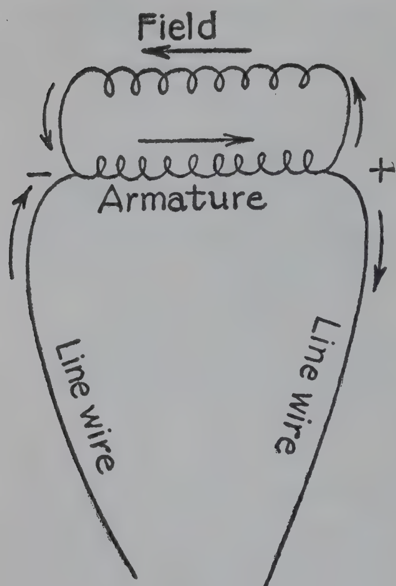


Fig. 20

will be generated in the moving armature. This, however, will strengthen the field slightly, and as the field is strengthened the armature will generate more current, and thus by a mutual reaction the machine gradually "builds up" to full strength.

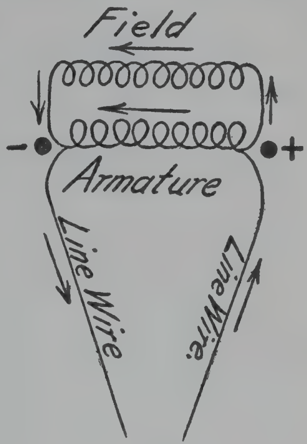


Fig. 21

When now we use the machine as a motor, an electric current must be sent along the line wires in the opposite direction (Fig. 21) from which it would come out of the machine when acting as a dynamo. It will then be noticed that, although the direction of the current through the field is the same, whether the machine is used as a dynamo or a motor, the direction through the armature, when used as a motor, is the reverse of that when used as a dynamo.

You may perhaps be able to notice that the amount of wire on the field is considerably more than that on the armature. Now if you will trace the wires carefully you will find that there is provided a way of supplementing the wire of the armature with some more wire in what is called the rheostat, Fig. 22. This wire, or

portions of it, is introduced into the armature circuit when the machine first starts. When, however, the machine has started and the armature is moving within the influence of a magnetic field, it plays the part of a dynamo at the same time that it is acting as a motor. Two conflicting and opposite electro-motive forces therefore exist in the armature at the same time. In Fig. 22 the arrow *a* represents the direction of the electro-motive force which is impressed upon the armature, and the arrow *b* represents the the counter-electro-motive force which the moving armature devélops.

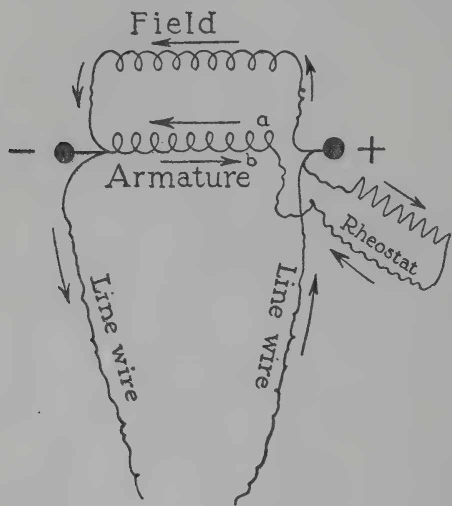


Fig. 22

This counter-electro-motive force, which develops while the machine is in motion, makes it unnecessary to hold back the current longer by the extra resistance of the rheostat and hence that is usually cut out. Being used only for starting purposes

and looking like a box, it is generally called the "starting box." If now it was intended that this motor should run at a constant speed, as is often the case, no other governor would be needed than this counter-electro-motive force, for whenever the machine begins to go faster, on account of reduced load, its counter-electro-motive force increases as the speed and holds in check the impressed electromotive force. This acts very perfectly as a governor, and motors operate with notoriously constant speed under variable loads. But, of course, in this present instance the motor is required to work at a variable speed. It must pump air slowly for the soft passages of music, and it must work the pump to its utmost for the very strong passages.

To understand how an electric motor may pump an organ and have its speed automatically controlled, let us examine the diagram in Fig. 23. The motor *m* causes the shaft *S* to revolve, carrying the crank *C* around with it. The rod *r* causes *a b*, the lower side of the bellows, to rise and fall, this side being hinged at *b*. The side *b c*, is fixed. When the side *a b* is pushed upward by the crank rod the valve *f* closes and the air in the compartment *h* pushes open the valve *g* and enters the compartment *j*. The upper side *d e*, of this com-

partment rises as it is filled with air. Weights K, K, K, rest on the top of this and air ducts lead from this compartment to the pipes of the organ. The keys of the organ operate air cocks which open and close the air ducts connected

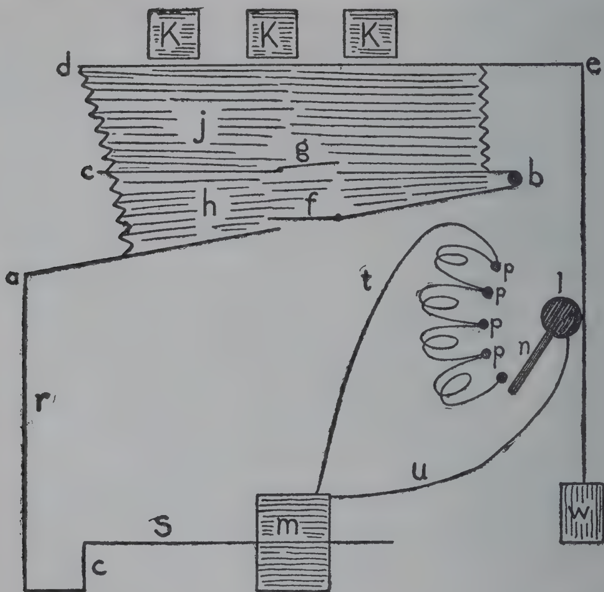


Fig. 23

with the organ-pipes. A chain connected with e passes around the axle of the wheel l and has a weight W upon its lower end. The wheel l carries a strip of brass n, which slides over metal points p, p, p, etc. The successive points are connected by coils of wire to furnish resistance. This

series of coils is called a rheostat. The wires *t* and *u* form a loop from the armature of the motor and connect this rheostat in series with the armature. *u* is connected with the brass strip *n*. Notice that when the compartment *j* is full of air and the side *d e*, is lifted to its greatest height the strip *n* is moved to the lowest point *p*, and the electric current must pass from *u* through all the resistance of the rheostat in order to get back to the armature by the wire *t*. This makes the motor go very slowly. When *d e* sinks down, the strip *n* moves to the upper points *p*, and the resistance is reduced step by step, enabling the motor to quicken its speed and pump faster as more air is required.

Small motors in order to be effective must travel at high speed. This motor when moving at its highest speed makes 1,800 revolutions per minute. The bellows on the other hand needs to be large and move slowly in order to be efficient. Hence the motor is not in reality connected directly to the shaft *S*, but causes the shaft to revolve by means of a series of pulleys and belts. The pulley on the motor is three inches in diameter. It is connected by a flat leather belt with a wheel thirty inches in diameter. When the motor there-

fore, makes 1,800 revolutions per minute this wheel makes 180 revolutions per minute. The axle of this wheel carries a small cog-wheel three inches in diameter and it is connected by a chain belt with a cog wheel on the shaft *S* (Fig. 23). Thus this shaft revolves thirty times per minute, that is, the rod *r* rises and falls each second. A pull of one pound on the rim of the motor pulley will cause a pull of sixty pounds on the cogs of the wheel upon the shaft *S*. If the second belt were leather, a sixty-pound pull would cause it to slip on the smaller pulley. Hence the second belt is a steel chain and the wheels have cogs, or sprockets, like a bicycle.

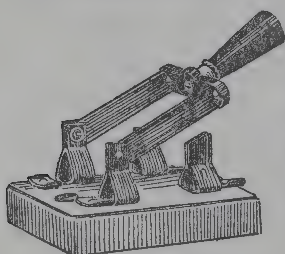


Fig. 24

The organist before beginning to play closes a double-pole, single-throw switch (Fig. 24), which sends the electric current to the motor.

The motor pumps air until the bellows is full, and if the organist delays playing, the strip of brass *n* (Fig. 23) is carried below the lowest point *p*, thus cutting off the current and stopping the motor. As soon as he uses some of the air in the bellows, however, *n* rises and makes contact with the points *p* and the motor starts.

This suggests that a somewhat similar thing is accomplished under electric cars which have air brakes. An electric motor pumps the air and compresses it in a tank. When the pressure reaches a certain point, say sixty pounds per square inch, it automatically shuts off the electric current from the motor which works the pump. But when the motorman uses some of the air to apply the brakes to the wheels, and the pressure in the tank falls below sixty pounds, the electric current is again automatically turned on to the motor.

Of course if an electric motor can operate a pump to compress air it may also work a pump to exhaust air. This is what is done in a vacuum cleaner. The electric pump as it is called (which means a pump worked by an electric motor), exhausts some of the air from a compartment in the machine, and the atmosphere pressing in through nozzle and hose carries dust from rugs and furniture with it into the compartment. The best vacuum cleaners will produce a pressure of seven or eight pounds per square inch, about half an atmosphere. This will remove dust from the warp and woof of a rug better than our greatest hurricanes can when the rugs are hung upon a line. There are three

kinds of air pumps in use with vacuum cleaners: (1) bellows, (2) rotating disk or fan, (3) piston.

To milk cows by electricity is simply to apply the vacuum-cleaner idea to the process, and, in general, doing things by electricity usually means doing them by some machine that is made to go by an electric motor. This then is the first key to the Electrical Show, and if you will remember to look first for the motor it may remove much of the mystery from some of the exhibits. In many cases it is not necessary to have a complete electric motor, but simply an electro-magnet to do the work. In booth No. 56 you will find a piano played by electricity. Its keys are moving, but no hands strike them. There is no ghost at work here. A little strip of iron has been placed upon the under side of each key and a small electro-magnet is placed under that. It is only necessary that wires should run from these electro-magnets to two dry-battery cells and to push buttons, and a person far away may play the piano. In reality, however, it is not a person but a roll of punctured paper that opens and closes the electric circuits to these various magnets underneath the keys.

It often happens that you see a person playing a pipe organ with his keyboard far removed from the organ itself. In this case the keys simply act as push buttons to close the electric circuit through electro-magnets placed in the organ itself. These electro-magnets operate the air valves of the various pipes.

You call at some apartment house where there is no hall boy, but a row of push buttons labelled with the names of the tenants. You push a button and the door which was locked opens apparently of its own accord. To say that the door opens by electricity is only to add mystery. What does happen is that an electric bell up in the apartment rings in response to your push of the button, and in reply the tenant pushes a button and the door is unlatched by an electro-magnet concealed in the door casing (Fig. 25).

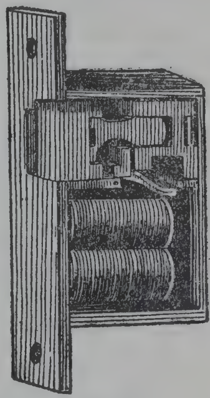


Fig. 25

So I would say that the first key to the Electric Show or to the multitude of electrical appliances which you meet in life is the electro-magnet. Consider the motor as one illustration of its use.

If you are really to understand the Electric Show you should go twice. I advise going with this key alone first and note down all the applications of electro-magnets which you can find there. When you have done so I shall be glad to have your report.

VI

APPLICATIONS OF THE ELECTRO MAGNET

IT became quite the rage now among the boys to find as many uses of electro-magnets as possible. These were reported and explained to the club and a list kept. This list included:

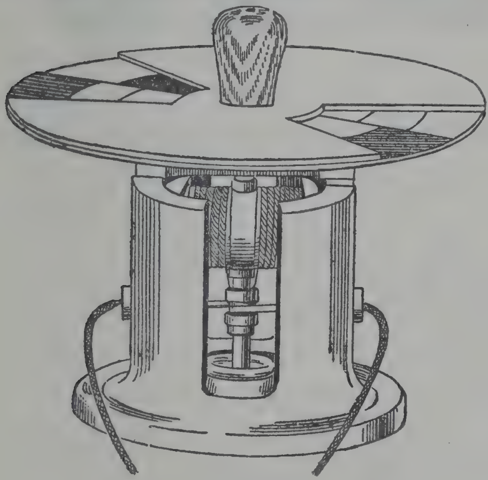


Fig. 26

1. Dynamo.
2. Magneto.
3. Ammeter.
4. Wattmeter.
5. Motor.
6. Electric piano and organ players.
7. Electric door openers.

Already noticed in the preceding pages, and the following:

8. *The Electric Spinner* (Fig. 26).—A toy full of instruction. The standard is a steel magnet which produces a magnetic field. Inside of this is an electro-magnet which serves as an armature. Plainly

visible on its shaft is a commutator to which the electric current from a dry cell is sent. This causes the armature to revolve and carry with it a series

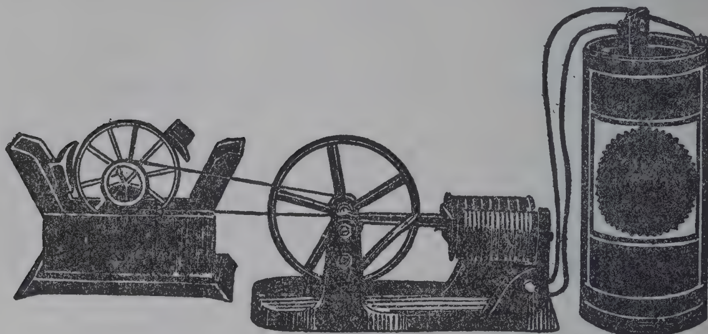


Fig. 27

of colour disks which may be adjusted so as to show what tint or shade results from mixing colours in various proportions.

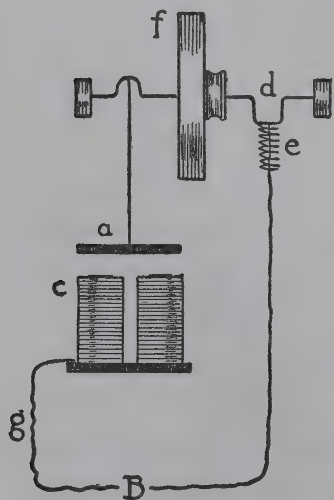


Fig. 28

9. *The Electric Engine* (Fig. 27).—This toy, with one dry battery cell, develops power enough to run several other toy machines. The diagram in Fig. 28 will make its plan of operation plain. *B* is the battery cell, *c* the electro-magnets, *a* an armature of iron. By a rod this armature is connected with a crank on

the axle which carries the fly wheel *f*. Another crank, *d*, upon the same axle serves like a push button to close the electric circuit at the right instant. The wire *g* from the battery cell encircles the electro-magnet *c* and then is connected to the iron base of the toy. When the crank *d* touches the conductor *e*, which is a spring, the electric current passes around the magnet, the magnet pulls the iron armature *a*, and this gives an impulse to the wheel *f* whose momentum carries it around during that portion of the revolution when *d* is separated from *e* and *a* is receding from the magnet.

It is customary to say that the circuit is closed through the base of the machine, but this language requires interpretation. It means that a way is provided for the electric current to pass through the base. A person who is expert in language but not in electricity might expect us to say "the circuit is open through the base."

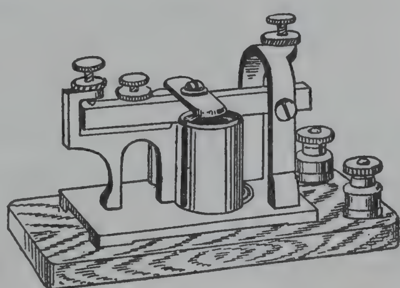


Fig. 29

10. *The Telegraph Sounder* (Fig. 29).—This was

a toy half a century ago, but since the days of Samuel Finley Breese Morse it has become of vast commercial importance. The Western Union Telegraph Company in 1909 had 211,513 miles of poles and cables, 1,382,500 miles of wire, 24,321 offices, sent 68,053,439 messages, received $30,541,072.55, expended $23,193,965.66, and had $7,347,106.89 in profits. In the United States more than 93,000,000 and in the world at large more than 600,000,000 messages are sent annually, and there are men still living who scoffed at Morse's ideas as *impracticable.*

It is interesting to contemplate what would happen to the Stock Exchange, to the newspapers, to the railroads, to the congressman addressing his constituents from the floor of a legislative chamber, to business in general, if the world were deprived of the telegraph.

A few years ago a telegraph despatch was sent from New York to San Francisco, Tokio, London, and back to New York, 42,872 miles, in three minutes less than an hour. Electricity can travel around the world in a fraction of a second, the time was consumed in repeating the message. I once sent a message from New York to New Haven to announce that I was coming, and afterward took my train and reached New Haven in time to receive my own

message and pay the messenger boy. But I have never lost faith in the beneficent results of Morse's labours.

Morse (1791–1872) was an artist and the first President of the National Academy of Design. He was likewise a professor in New York University and constructed his first experimental telegraph line upon the University campus in 1835. His first public line was built from Washington to Baltimore in 1844. The Western Union Telegraph Company was incorporated in 1856. Of course the work of Morse rested upon that of Oersted, in Copenhagen, who, in 1819, discovered electro-magnetism, and upon that of Joseph Henry of Albany, who in 1827 first insulated the wires.

The application of the electro-magnet to producing telegraphic signals will be understood by referring

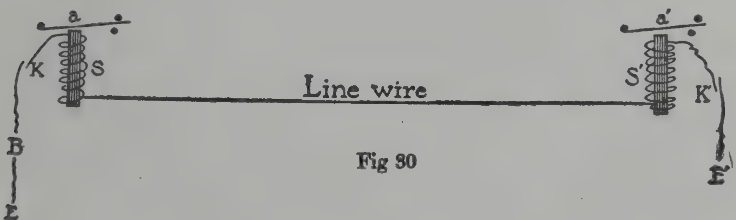


Fig 30

to Fig. 30. *B* is the generator of an electric current — sometimes a battery and sometimes a dynamo. One wire from this goes to the earth, *E*. The other

wire goes through a key, which, like a push button or a switch, serves to open or close the circuit. This is normally closed when not in use. Through this the current passes around the electro-magnet *S*, which attracts the armature *a*, causing it to click against a metal stop, hence it is called the sounder. From this the current passes along the line wire to a distant station and there through the sounder and closed key to the earth. There is likely to be a generator at each station. The current must run continually through the system. If a battery is employed, the copper sulphate, or gravity cell, to be described later, is chosen, because it will endure continued usage better than any other.

The operator, in sending signals, opens the circuit, the magnets cease to hold down the armatures, and they are raised by springs and strike against metallic stops above. It is customary to say that the circuit is completed through the earth. This statement misleads some persons into imagining an electric current capable of corroding water pipes and decomposing chemical compounds, passing through the earth between stations.

Perhaps it will help to a better understanding of the truth if we think of a city pumping water out of the ocean, say to fight fire, and disposing of it

Photograph by Helen W. Cooke

Testing the Telegraphy Outfit

again into the ocean. The ocean currents thus produced are not likely to be destructive. Indeed, just as we measure height from the ocean level as zero, so we measure electric pressures as from the zero level of the earth's electrical state.

The key used by telegraphers is represented in Fig. 31. It has connected with it a switch to keep the circuit closed when the key is not in operation. The Morse code of signals consists of dots and dashes, when printed, as follows:

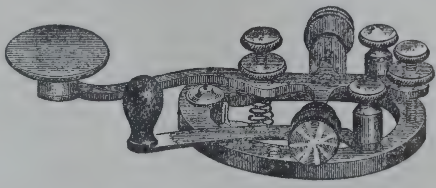


Fig. 31

a . —
b — . . .
c . . .
etc.

Operators learn to read the message by the intervals between sounds. A dot consists of two taps of the sounder with a short interval between, and a dash consists of two taps with a longer interval between. One tap of the sounder is caused by its descending upon the metal stop below and another by its rising against the upper stop.

Telegraph sounders are operated on about a

quarter of an ampere of current if from a battery circuit, or on about one tenth of an ampere from a dynamo circuit. The dynamo circuit is supplied with more volts of electric pressure, and hence its power is ample to cause the armature to strike the metal stops hard enough to be heard by the operator.

For example a battery circuit may supply to the sounder a current with these characteristics:

2 volts $\times .25$ amperes $= .5$ watts,

while a dynamo circuit may give:

2 volts $\times .1$ ampere $= .6$ watts.

Telegraph line wires are usually bare, the insulation being merely the glass knobs at the poles. Clean water is a very good insulator but dirty water is a fairly good conductor. A wet telegraph pole may bring so much current to earth as to prevent all sounders on the line from operating. Hence the line is separated from the poles by glass. The poles are about one hundred and thirty-two feet apart, making forty to the mile. The wires are usually galvanized iron one sixth of an inch in diameter. Copper conducts six times as well as iron, and is now replacing iron in the lines.

Morse laid a submarine telegraph line in New York Harbour and suggested a cable across the

ocean. But that gigantic undertaking had to await the masterful intelligence of Lord Kelvin and the indomitable will of Cyrus W. Field. A submarine cable was laid across the Strait of Dover in 1850. It was cut by the anchor of a fisherman a few hours after it was laid. The first attempt to lay a submarine cable across the Atlantic Ocean was made in 1857. Two ships of war, the *Agamemnon* of Great Britain and the *Niagara* of the United States, engaged in this undertaking. Three hundred miles had been laid when the cable parted where the ocean was more than two miles deep. William Thomson was on board the *Agamemnon* as electrical expert. He went home to study and improve the methods. The next year, 1858, the *Agamemnon* and the *Niagara* met in midocean each with a portion of the cable on board. The splice was made, and the *Agamemnon* started toward Ireland and the *Niagara* toward Newfoundland. When six miles apart the cable broke. The ships met again, made a new splice and again started in opposite directions. They laid eighty miles and the cable parted a second time. They met again, spliced and laid two hundred miles when it parted for the third time. They met a fourth time, made the splice and succeeded in laying

the first cable from Ireland to Newfoundland on August 5, 1858.

In a few weeks the insulation failed and no more messages could be sent. Seven years were spent in studying the problem, and again in 1865 the *Great Eastern*, a mammoth ship, started to lay the cable. William Thomson was again on board as the expert. When twelve hundred miles had been laid the cable parted in deep water. Three times the cable was grappled and brought part way to the surface and lost again. The *Great Eastern* returned to land. The next year, 1866, the *Great Eastern*, having on board William Thomson (Lord Kelvin), Mr. Canning, the engineer of the expedition, and Captain Anderson, in command, laid the cable which has worked successfully ever since. Thomson, Canning, and Anderson were knighted as a result of their labours. Sir William Thomson (1824–1907), afterward Lord Kelvin, is credited with having solved the difficult electrical problems connected with this enterprise. Cyrus W. Field (1819–1892), born in Stockbridge, Mass., helped to secure the many millions of dollars necessary to carry the work to completion.

There are now seventy-three cables connecting Europe and America, and two across the Pacific

Ocean. Cable rates are: New York to England France, Germany, or Holland twenty-five cents a word, to Switzerland thirty cents a word, and to Japan one dollar and thirty-three cents a word.

The boys were kept very busy now looking up historical and biographical sketches, as well as working up the many applications of the electro-magnet. The next to be reported was:

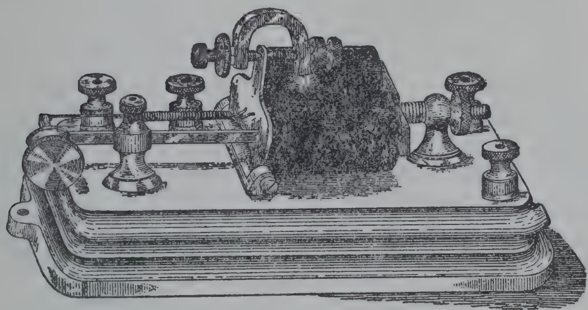


Fig. 32

11. *The Relay* (Fig. 32).—Telegraphing from 3,000 to 10,000 miles under the ocean is full of difficulties not now to be explained.

Of course when we attempt to telegraph many miles upon land we find that the resistance of the wire cuts down the strength of the current so that it will not move the sounder. This, however, is readily obviated by the relay devised by Morse. It simply serves as an automatic key to close a

circuit. A diagram will make this clear (Fig. 33). Suppose the line wire to be very long and on account of its resistance the current is too feeble to operate

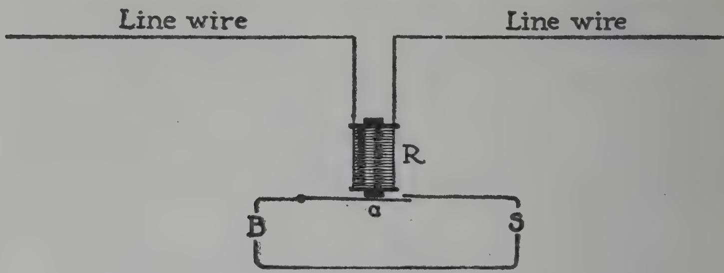


Fig. 33

a sounder. It is likely to be about .025 ampere where the local sounder may require .25 ampere or ten times as much. It is easily possible to wind a magnet (Fig. 33), *R*, such that .025 ampere will close the armature *a*, so that it may complete a local circuit when it would not make noise enough for a sounder. *B* may represent a local battery of any desired strength which may operate the sounder *S* of that station as loudly as may be desired.

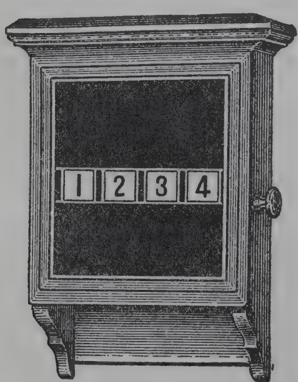


Fig. 34

12. *Annunciator* (Fig. 34).— We live in a fifth-floor apartment. When we push

the button to call the elevator a No. 5 appears in the annunciator in the elevator car. This tells the elevator boy where the call comes from. Take out two or three screws and the annunciator opens, revealing a series of electro-magnets like the one shown in Fig. 35. When an electric current passes around the coil it pulls back an iron catch and allows a number to drop so as to show through a small window. The elevator boy, having noted that the call is from the fifth floor, pushes up the number and the iron catch holds it until the coil is magnetized again by an electric current.

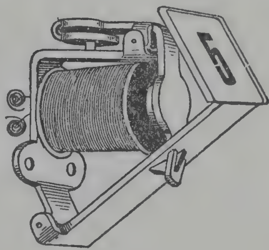


Fig. 35

The annunciator has a bell to call attention. A cable of six wires enters this annunciator (Fig. 36). One wire goes direct to the bell and the other five reach the bell through the separate coils of the electro-magnets which control the drops. But how are

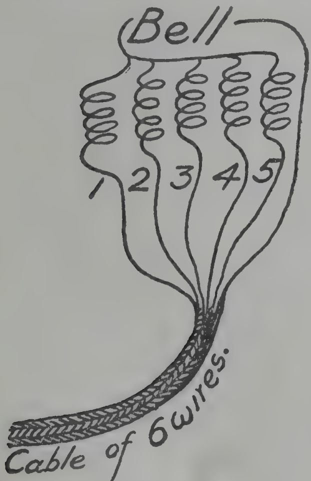


Fig. 36

electrical connections made between a moving elevator car and the push buttons on various floors? The diagram in Fig. 37 shows this in elevation. *B* represents a battery of several dry cells located

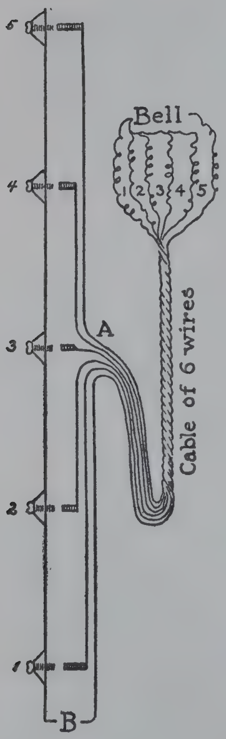
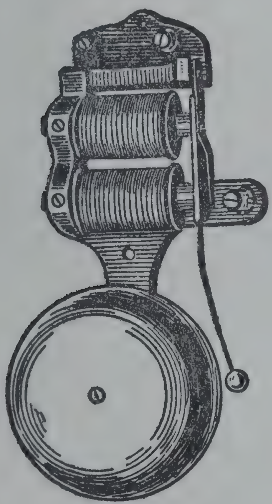


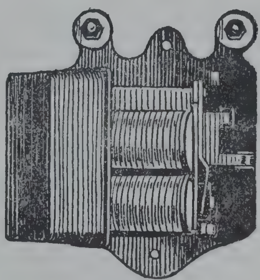
Fig. 37

in the basement. One wire from it runs direct to the push buttons 1, 2, 3, 4, 5, located upon the five floors of the house. The other wire from the battery, together with wires from each of the five push buttons, all run to a point, *A*, half-way up the elevator shaft. Here the six wires are gathered into a cable long enough to reach either to the top or the bottom of the elevator shaft. The other end of this cable enters the elevator car and runs to the annunciator. The wire from the battery goes direct to the bell. The wires from the various push buttons go through correspondingly numbered electromagnets to the bell. When, therefore, we pushed the button on the fifth floor, we closed the gap in the electric circuit at that point. The current

came up from the battery, passed through the button, went down the cable to the car, went through electro-magnet No. 5, went through the bell, and returned direct to the battery, thus completing the circuit. Annunciators are used about buildings to call other attendants, besides the elevator boy. They are likewise used in burglar alarms to inform the householder which door or window is being forced. They are used in the fire department to tell what part of the city the call came from.



Bell



Buzzer

Fig. 38

13. *The Electric Bell and Buzzer* (Fig. 38).—So common a thing as an electric bell really belongs to

the present generation. Bells were either novelties or toys when I was your age. They cost then many times what they do now and then were poorly made. Nobody dared to trust them for front-door bells. It was necessary to have a card permanently posted over the push button saying, "If the bell does not ring, knock." In those days batteries were troublesome to care for, houses were not wired when built, and no one had learned the art of concealing the wires neatly.

The buzzer is simply a bell minus gong and hammer. Those shown in Fig. 38 ring well on a single dry cell. A cell costing twelve cents operated one for two years while it was used as a call bell from dining room to kitchen, the current required being .15 ampere.

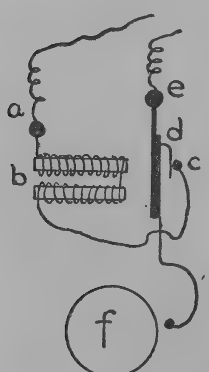


Fig. 39

The connections are shown in the diagram (Fig.39). Suppose the current to enter at the binding post *a*, pass around the magnets *b* and then to the post *c*. The armature *d* normally rests against the post *c* and the current finds its way along this to the post *e* and thence back to the battery. But as soon as the current passes, *b* be-

Photograph by Helen W. Cooke

Electric Bell

comes a magnet and pulls the armature *d* away from the post *c*, thus breaking the circuit, when *b* ceases to be a magnet and a spring pushes the armature *d* back against the post *c* to repeat the operation. The armature *d* carries a hammer which strikes the gong *f*. If the wire, which is usually connected with the binding post *e*, is connected with the post *c*, the "clatter" bell is changed to a "single-stroke" bell, and if the gong and hammer are removed the "bell" is changed to a "buzzer."

In the case of the buzzer, by changing the length of the armature or by weighting it, we may change the time of its vibrations and its tone. The connections between battery push button and bell form a complete circuit. In Fig. 40 *B* represents a battery, usually of dry cells, *B′* represents the bell, and *P* represents the push button. The electric circuit is "open," (that is, there is a break in the conductor) at *P* until some one "pushes the button," that is, simply pushes against a spring so as to cause a piece of metal to bridge the gap in the conductor. Then we say the circuit is "closed."

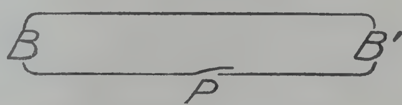


Fig. 40

Push button devices and switches are innumerable. In every case they are simply devices for pushing one piece of metal against another and completing

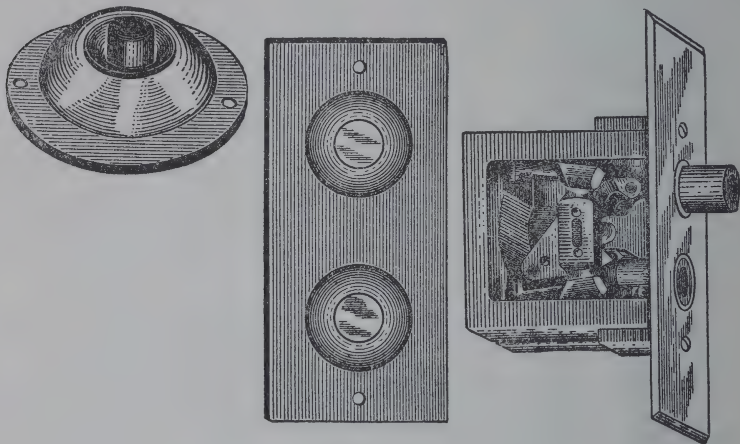


Fig. 41

the circuit for an electric current. Every one should unscrew and examine a few of them, both for the pleasure of seeing how they work and to learn how

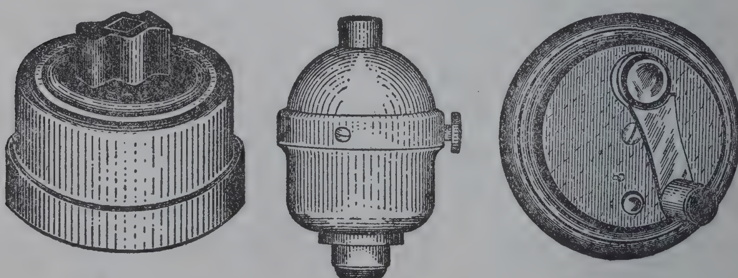


Fig. 42

to make them work when they sometimes fail. Not only in bells but in all other instruments where

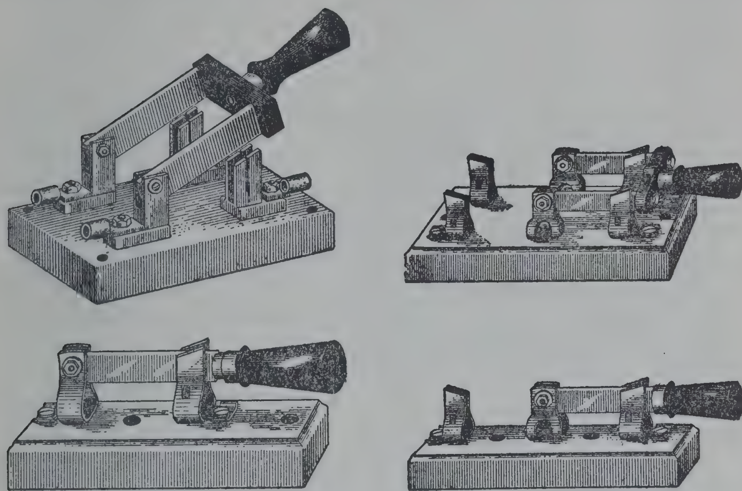


Fig. 43

electro-magnets are used, the magnets are placed in pairs, fastened together upon an iron base. They are wound so that the free ends are made opposite poles by the electric current. Like a horseshoe magnet, they form one magnet. The two poles thus placed are mutually helpful and each is stronger than it would be if separated from the other.

14. *Electric Clocks, Self-winding Clocks, Programme Clocks.*—A pretentious-looking thing which appeared like a dish pan with a glass bottom was opened by the boys and found to be the simplest of all clocks.

It had an electro-magnet like that in Fig. 44. A strip of iron acting as an armature across the free ends of this magnet, pushed like a finger against the cogs of a wheel. This wheel was on the axle of the minute hand and it had sixty cogs. The electric circuit was closed through the magnet for an instant each minute and the armature pushed the wheel ahead one cog. Thus it made one complete revolution in an hour. A train of four other cog-wheels caused the hour hand to trail after at one twelfth the speed of the minute hand. This machinery made simply a small handful in an eighteen-inch stamped-metal "dish-pan" costing fifteen dollars.

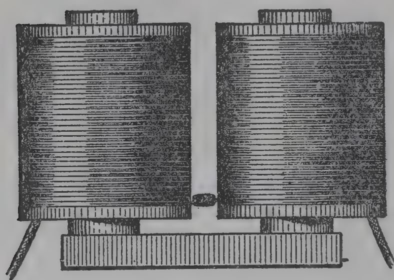


Fig. 44

A self-winding clock was opened and found to contain two dry battery cells, an electro-magnet which operated very much like that of a "clatter" bell, the hammer like a finger poking against the cogs of a wheel. Once an hour the long hand closed the circuit through the battery and the magnet and its armature swung back and forth long enough to give the cog wheel one complete revolution and

wind a spring, which it carried upon its axle. This spring kept the clock running one hour, until the next winding.

The programme clocks which were examined were self-winding clocks, but were connected by wires to the master clock which corrected them each hour. Each time the long hand of the master clock came to twelve it closed an electric circuit through all the clocks in the system. In each clock the current passed around an electro-magnet and caused it to pull an armature against a metal stop and set each long hand exactly at twelve. This master clock is sometimes situated many miles away and may correct the time for a whole city. Thus a master clock at Washington, D. C., furnishes standard time to all parts of the United States. The master

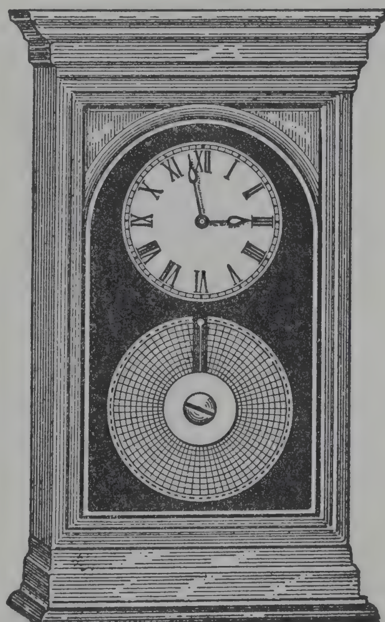


Fig. 45

clock which we examined also closed the circuit at proper intervals through a series of programme bells placed in the various class rooms, and these called and dismissed classes automatically.

15. *Watchman's Time Detector* (Fig. 45).—This is a device to compel a watchman to make his appointed trips. Push buttons or switches are distributed about the building at various points, and it is made his duty to close the circuits at these points at stated times. When he does so, the fact is recorded by electro-magnets puncturing, or, in some way, marking a revolving time card in the clock.

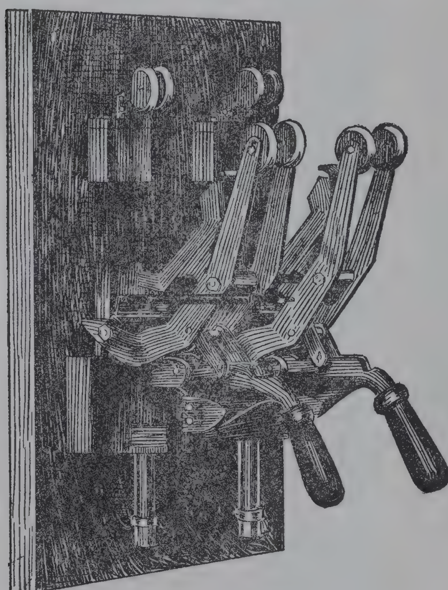


Fig. 46

16. *Circuit Breakers* (Fig. 46).—Electro-magnets are used to open switches and thus protect dynamos and other machines against a larger electric current than they are able to carry. The switch is held

closed by a spring which, by an adjusting device, may be tightened or loosened. A dynamo which we examined had its circuit breaker adjusted so that it would remain closed if any current under 1500 amperes passed, but if a greater current than that passed it would strengthen the magnet sufficiently to open the switch and thus break the circuit.

17. *Separating Iron from Ore.*—In 1897 Edison first proposed to use an electro-magnet to separate iron from crushed earth. Fig. 47 represents the process. *E* is an electro-magnet. *S* is the stream of crushed ore containing iron. Gravity would cause all the material to fall into bin *A*, but the electro-magnet *E* pulls that portion of the material which is magnetic to one side so that it falls into the bin *B*.

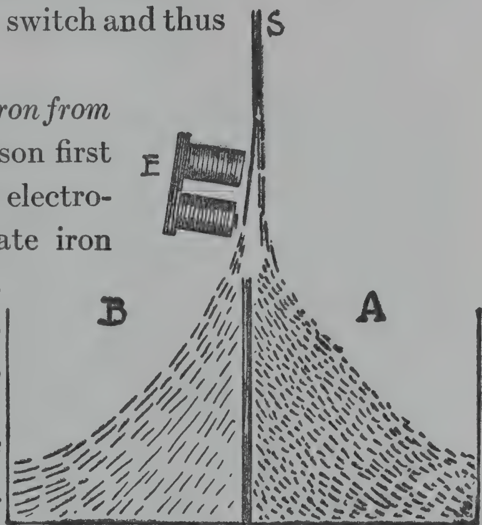


Fig. 47

18. *Lifting Magnets.*—Electro-magnets are made for use with hoisting apparatus to save the trouble of manipulating grappling hooks, etc. They may

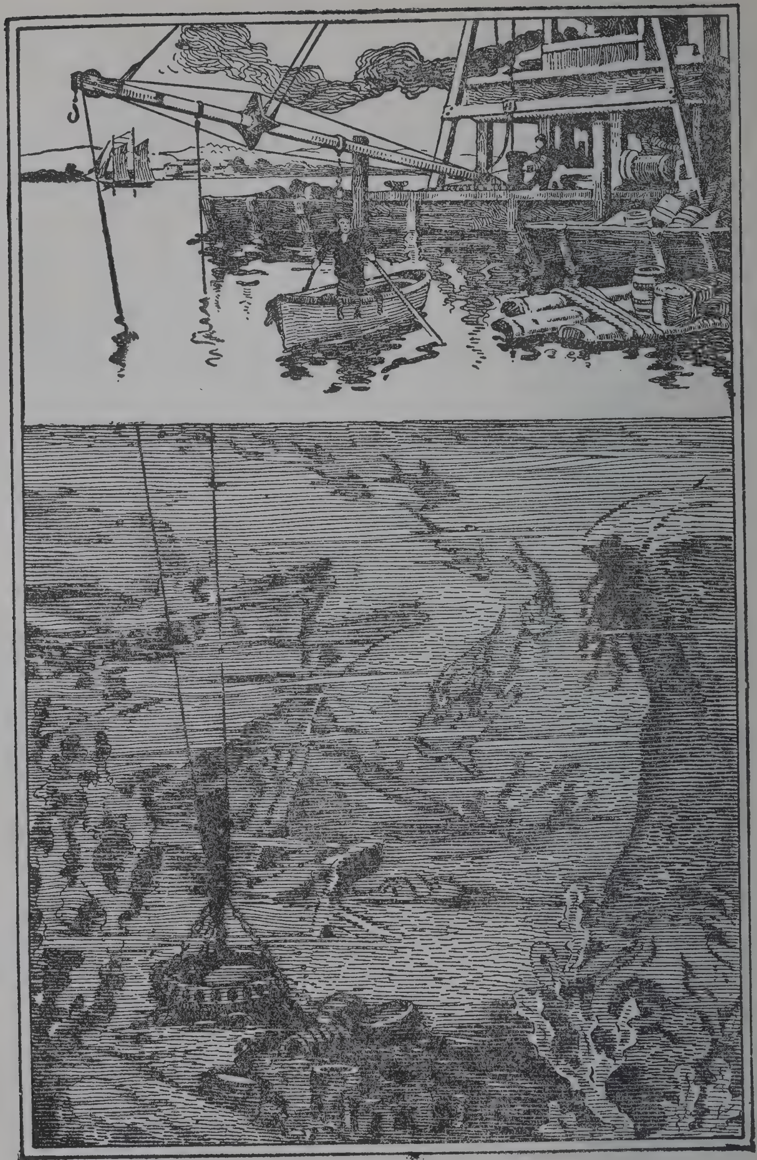


Fig. 48

lift barrels and boxes of iron, the wood of the barrel or box being transparent, we say, to the magnetic influence. That is, the magnet will attract iron through the wood just as light will shine through glass. Such magnets are used to pick up from the bottom of the sea cases of hardware from wrecked ships. (See the accompanying illustration, Fig. 48.) In such cases the electric conductors which lead to and encircle the magnets must be well insulated from the water of the sea, otherwise the electric current would take the shorter path from one line wire through the sea water, which is a fairly good conductor, and back by the other line wire, rather than go the path of greater resistance around the magnet. Electro-magnets are coming into use in foundries, etc., for lifting heavy iron castings.

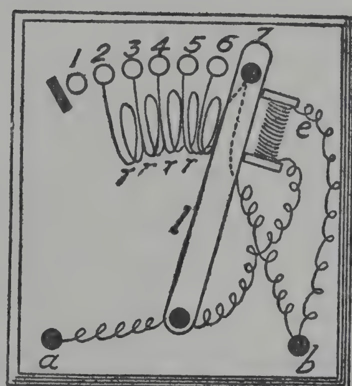


Fig. 49

19. *Electro-Magnet on Starting Box.*—As was explained under *electric motors*, a starting box is simply a series of resistance coils *r*, *r*, *r*, *r*, *r*, in Fig. 49. When the motor is not in use the switch *l* rests upon the point 1 and no electric current passes.

When the switch is moved to point 2, the current entering at *a* passes to the pivot of the switch and up the metal strip *l* to the point 2, then around the series of coils, *r*, *r*, *r*, *r*, *r*, to the post *b* and thence back to the generator. As the switch is moved to the right, the current passes through less and less of this resistance until, when it reaches point 7, all the coils of resistance are "cut out," that is, they are not in the path of the current. Now the motor has reached its full speed and is developing enough counter-electro-motive force to protect itself against too much current. Through a shunt, however, a portion of the current passes from *a* to *b* around the electro-magnet *e*, the two poles of which are presented to the metal strip *l*, which must be of iron. This magnet holds the switch over so long as the current is on, but when the current is cut off, by opening a switch in the line wire, *e* ceases to be a magnet and *l* is carried back to point 1 by a spring. Thus an extra resistance must always be in circuit when the motor is first started. Those who start motors are expected to move the lever *l* of the starting box slowly from point to point, pausing a second or two on each to give the motor time to acquire proper speed for its protec-

tion. How too great a current would "burn out" a motor will be explained later.

The motor man handles a lever for starting his car, which works like that of the "starting box." His "starting box," however, is called a "controller." Although it accomplishes the same result as the starting box it has a wholly different and vastly more complex mechanism than that already described.

The elevator boy, who runs our electric elevator, handles a lever which also does the same thing through far different mechanism. Indeed, in his case electro-magnets are used to prevent him from cutting out resistance too fast if he should move his lever too quickly.

20. *Starting Switches for Electric Elevators.*—The motor man has to be instructed particularly how he should handle the lever of his controller, and he is trusted to follow his directions to some extent, however lacking in intelligence and integrity he may be. But the elevator boy receives scarcely any instructions about his machine, and, indeed, his machine has been constructed pretty nearly "fool-proof." It will automatically correct his errors of management. If he throws the handle from one extreme to the other, all resistance cannot be

thrown out instantly, but this is accomplished by a series of electro-magnets closing one switch after another and thus cutting out resistance gradually.

21. *Arc Lamp Feed.*—As will be explained later, an arc lamp must have its carbons touching one another when the current is first thrown on, and then the carbons must be drawn apart from a quarter to half an inch. The upper carbon is lifted away from the lower one by a portion of the current passing by means of a shunt around an electro-magnet.

Fig. 50

22. *Volt Meter.*—The volt meter measures the pressure of an electric current. The volt meter which we examined looked outside like our ammeter, and when we removed the face it appeared inside like an ammeter. There was the steel magnet of horseshoe shape to furnish a field (Fig. 51), and there was an electro-magnet poised between its poles for an armature. The armature in the volt meter, however,

had wound upon it finer wire and more of it than was the case in the ammeter. There was no shunt wire in the volt meter as there was in the ammeter. We connected in series a fluid cell (to be described later), the ammeter, and the volt meter (Fig. 52). The ammeter shunt was removed so that all the current went through its armature. The volt meter needle went to one which was two thirds of the scale (Fig. 53), and the ammeter needle indicated .016. That is, this particular cell can push sixteen thousandths of an ampere through the resistance of this volt meter, and .016 am-

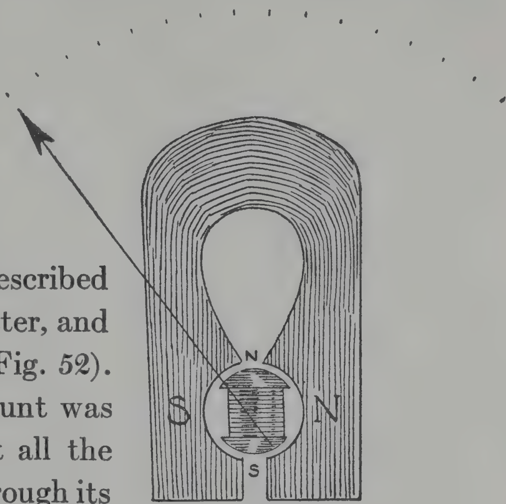


Fig. 51

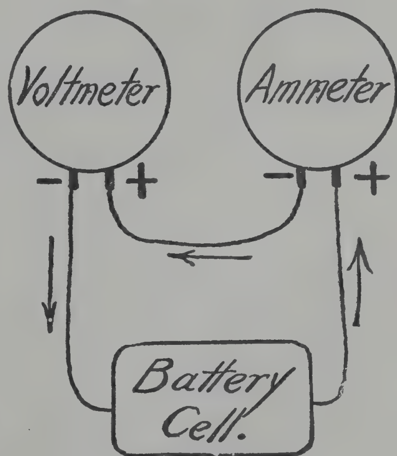


Fig. 52

pere passing through the armature of this volt meter will magnetize it sufficiently to move it against its spring, say sixty degrees.

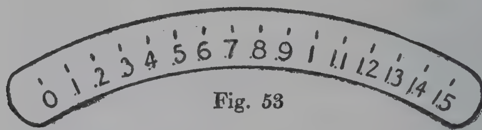


Fig. 53

We put into the circuit a lot more fine wire for resistance, *R* (Fig. 54), so that the volt-meter needle went only half as far as before, that is to .5. The ammeter indicated only half as much as before, that is .008 ampere. We put in resistance enough to bring the volt-meter needle down to .25 and the ammeter indicated one quarter of the original current. We put in less resistance, bringing the volt-

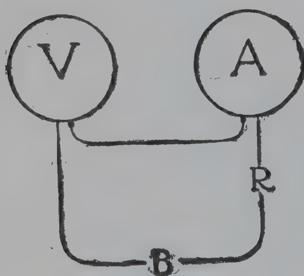


Fig. 54

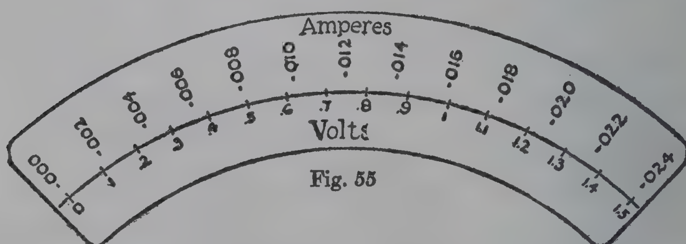


Fig. 55

meter needle to .75, and the ammeter indicated three fourths of the original current. Evidently the

volt meter is merely an ammeter with a different scale marked upon its card. With a pen we marked upon the card of the volt meter a true ammeter scale (Fig. 55).

In order to understand the volt meter, let us turn our attention for a moment to Fig. 56. I have arranged the water tank *T* at such a height above the faucet F that when the faucet is opened one quart of water will flow in a minute. If I partially close the faucet, making the opening one half as large (that is, offering twice the resistance to the flow), half a quart will flow in a minute. If I make the resistance four times as great only one quarter of a quart will flow in a minute. It is evident that I could arrange a scale underneath the handle of the faucet to indicate the quantity of water flowing, just as the ammeter and volt meter indicate the quantity of electricity which flows. If now that much is understood, it will be easy to learn how the water faucet may be used to measure water pressure and the volt meter in like manner used to measure electric pressure.

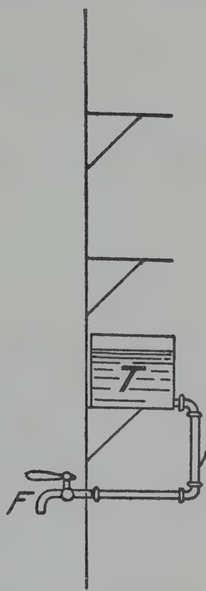


Fig. 56

Having set the faucet so that a quart will flow per minute, let us put on a longer tube p, and move the tank up to another shelf so that the distance from the water level in the tank to the faucet is twice as great as before. Under the increased pressure water runs through the faucet twice as fast and we now get two quarts per minute.

I purposely placed the tank out of sight behind a partition so that you might practise judging the water pressure by the flow at the faucet. We cannot very well talk about pressure in quarts. We might talk about it in pounds, but if we used this apparatus much we should probably get into the habit of talking about the pressure from one shelf, two shelves, three shelves, etc.

In order that the pressure might remain nearly constant during the experiment we would probably introduce resistance (that is, partially close the faucet) so that the water level should not fall much. We might, for example, set the faucet so that half a pint would flow in a minute when the tank was on the first shelf. Then a pint per minute would flow when the tank was on the second shelf and one and a half pints per minute when the tank was on the third shelf, etc. Thus we should infer the pressure by measuring the quantity.

One more illustration and the case will be clear. To save the trouble of measuring the quantity of water which flows through the faucet, suppose I introduce the device represented in Fig. 57. *W* is a small water wheel comparable to the armature of the volt meter. It carries a pointer which moves over a scale just as in the case of the volt meter.

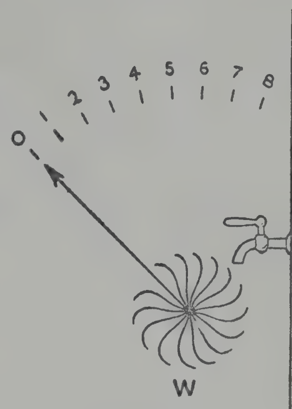


Fig. 57

It has a spring coiled around its axle which tends to keep the pointer at *o*, as in the case of the volt meter. The tank is placed upon the first shelf, the faucet is fixed so that a small amount of water flows and the needle moves to a certain figure upon the scale. We will mark this point one and call it "first-shelf pressure." The tank is lifted to the second shelf and the index moves to another point, which we will mark two and call it "second-shelf pressure." The tank is lifted to the third shelf and the index moves to a third point, which we will mark three and call it "third-shelf pressure," etc.

Ordinarily we measure water pressure with an instrument which allows no water to run to waste,

but in measuring electric pressure by the volt meter some current must pass through the instrument, just as in the case of our water-wheel illustration in Fig. 57. We put in large resistance so as to make this current as small as possible, while we let enough pass to move the armature.

Now let us return to the volt meter itself. By referring to Fig. 55, we see that it requires .024 ampere to move the needle of the volt meter clear across the scale, and we have found that one fluid cell was able to send enough current through the resistance of the armature to move the needle two thirds of the way across the scale. At this point we find Fig. 1, which might be read "one-cell pressure." We prefer to commemorate the name of one of the workers in the field of electricity and call this pressure a "volt" after Alessandro Volta (1745–1827), born at Como, Italy. It is the electric pressure which is produced by one fluid cell of a certain kind. We say, then, that one volt pushes through the resistance of this armature .016 ampere. Half a volt would push through the resistance of the armature half as much current

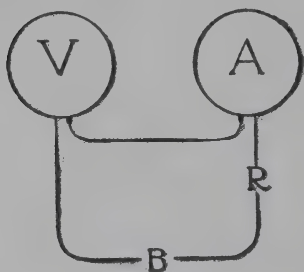


Fig. 58

or .008 ampere. At this point we put .5. Thus each of the figures in the lower row (Fig. 55) shows what part of a volt is required to send enough current through this particular armature to move the needle to that point.

We found out how much wire was wound upon the armature and put exactly the same amount in the outside resistance, *R* (Fig. 59). The needle now showed that one volt is able to push through twice the resistance of the armature only half as much current, and the needle stopped at .008 ampere. If this were to be the resistance in the

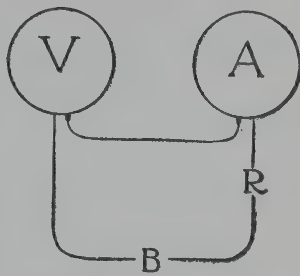


Fig. 59

volt meter circuit one volt should stand under .008 ampere and two under .016 and three under .024. It is evident then, that, if we know the internal resistance of a volt meter, we may make it capable of measuring greater electrical pressures by adding the proper amount of resistance. By putting at *R*, (Fig. 59) nine times the internal resistance of the instrument, thus multiplying the total resistance tenfold, the figures upon the scale of volts may be read as whole numbers from one to fifteen. In this case it will require fifteen cells to push the needle clear across

the scale and ten cells to push it two thirds of the way across. If now we add enough external resistance to multiply the resistance of the armature a hundred fold it will require 150 volts to push .024 of an ampere through the armature and pull its needle clear across the scale. In this case the figures upon the scale of volts are multiplied by one hundred and read from ten to one hundred and fifty. Such a scale would adapt this volt meter for use with our 110-volt lighting circuit. Volt meters are made with a series of such external resistances, called "multipliers," attached so that they may be easily thrown into the circuit.

It is evident that we need some term so that we may speak of quantities of resistance. This need has given rise to a unit of resistance called an ohm, after George Simon Ohm (1789–1854) born at Erlanger in Bavaria. Two inches of No. 36 German silver wire, such as is wound upon the armature of this volt meter, gives one ohm of resistance. There are 125 inches of this wire upon the armature. Its resistance is, therefore, 62.5 ohms, and we may, therefore, say that one volt of electric pressure can push through 62.5 ohms of resistance .016 of an ampere of current. Ohm

discovered this relationship in 1827, and formulated it as follows:

$$\frac{\text{volts}}{\text{ohms}}=\text{amperes (not, however, using these words).}$$

$$\frac{1 \text{ volt}}{62.5 \text{ ohms}}=.016 \text{ ampere.}$$

$$\begin{array}{r} 62.5)\ 1.0000\ (.016 \\ 625 \\ \hline 3750 \\ 3750 \\ \hline \end{array}$$

This is called Ohm's law, as every candidate for college admission will hear and hear again.

Volt meters and armatures for the alternating current have electro-magnets for their fields as well as for their armatures. Such instruments are equally well adapted for either direct or alternating currents. For when the current reverses its direction it reverses in field and armature alike, and thus a repulsion between like poles is maintained. Such an instrument, however, cannot respond to as slight a current as those previously described, since they must consume some energy in both field and armature.

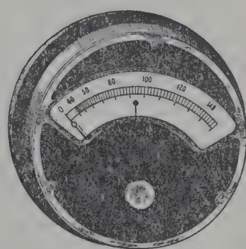


Fig. 60

23. *Telephone Receiver* (Fig. 61).—It requires a

stretch neither of the imagination nor of the truth to call a telephone receiver an electro-magnet, although perhaps it has never been called that before. We took it apart and found that it consisted of a steel-bar magnet *m* (Fig. 62), with a small spoon of wire *w* around one end of it. The ends of the wire on the spool run along inside the hard rubber shell to the two binding posts *a* and *b* at the other end. A disk of sheet iron *S* is held in the large end of the case very near to, but not quite touching, the end of the magnet.

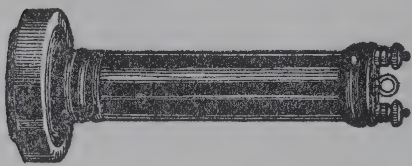


Fig. 61

When an alternating current is sent through the wire upon the spool it causes rapid changes in the strength of the magnetic field, if not reversals of the poles of the field, and the iron disk is made to vibrate, keeping time with the alternations of the current.

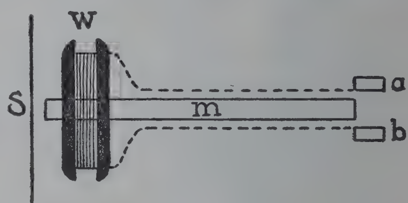


Fig. 62

In this laboratory we have seen that our current has sixty alternations per second. When it is connected with the receiver the disk, therefore, makes sixty vibrations per second, and produces

a tone which has very nearly the pitch of C two octaves below the middle C upon the piano.

24. *Spark Coil* (Fig. 63). — The automobile spark coil which we have already used is an electro-magnet. The battery sends a current through wire coiled around an iron core. At one end of this iron core is an iron armature which is made to vibrate in precisely the same manner as the armature of an electric bell. This makes and breaks the current and causes rapid changes in the strength of the field. A rapidly changing magnetic field may be used to develop electricity in a conductor, as we have already seen in the case of the dynamo.

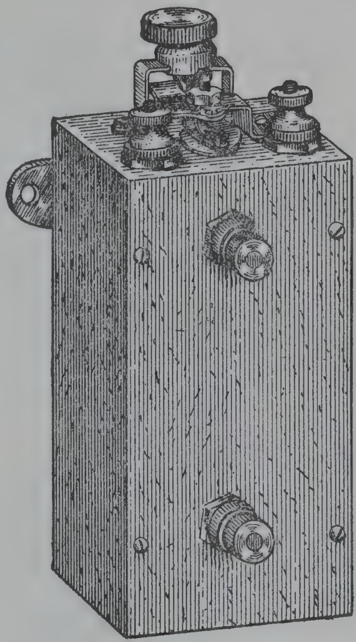


Fig. 63

How it is used in the automobile spark coil will be shown later. It is sufficient now to mention it as a case of a magnetic field produced by an electric current passing through a wire coiled around an iron core, or, in short, an electro-magnet.

Induction coils, Ruhmkorff coils, and transformers, to be described later, are closely related to this. They all create magnetic fields in the same way and are all electro-magnets.

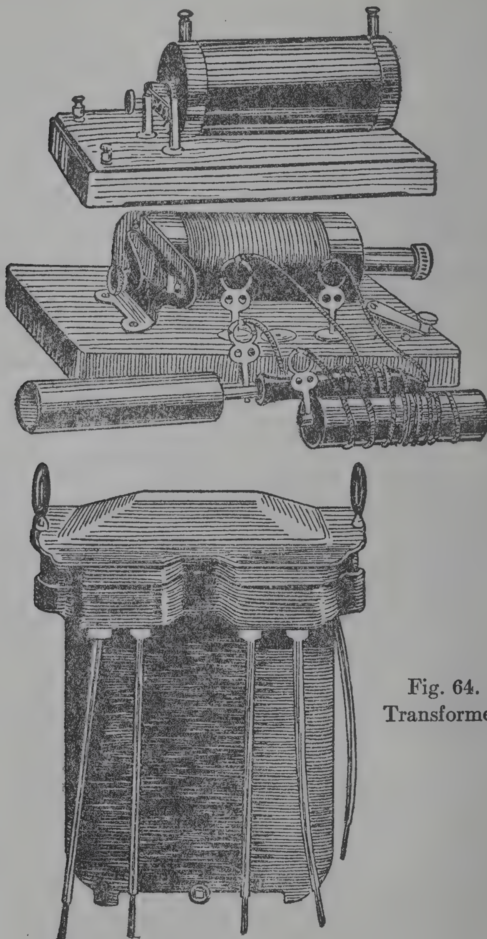


Fig. 64.
Transformers

VII

ELECTRIC HEATING

IT was Washington's birthday. The schools were to have a holiday and the Science Club was to hold a special, open meeting at which I had been asked to present the subject of electricity in the household. I replied to the programme committee that that was too large a subject, but that I would talk upon electric heating. I warned them, however, that it would be a dry study, and not an entertainment. They replied that the father of his country had been born at a time of the year when the weather was unfavourable to outdoor sports, and that February usually found them acclimated to vigorous study. Neither they nor their friends objected to study if it seemed to have a motive.

I found an audience composed of old and young, men and women, girls and boys. Most of them had left school — many of them because their teachers thought they were incompetent to continue.

Not far from here is "a wheel in the middle of a wheel . . . as for their rings they are so high that they are dreadful . . . and the spirit of the living creature is in the wheels." Those wheels are now

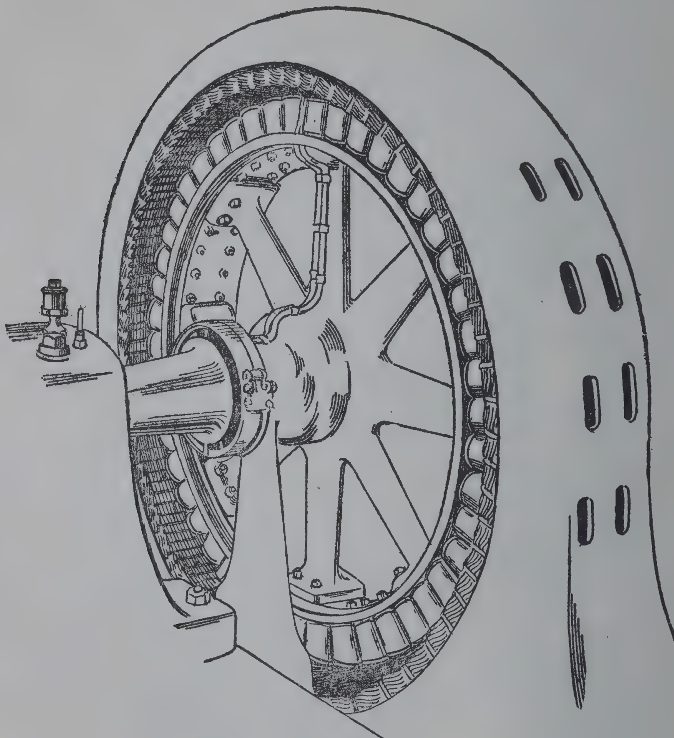


Fig. 65

sending the electric current to this room for our experiments. I propose to show that we convert electricity into heat by offering resistance to its flow. Experience teaches us that resistance to motion always produces

heat. At Niagara Falls thousands of tons of water descend at the rate of one hundred and sixty feet in three seconds. When the water reaches the bottom of the falls, it is moving a little faster than a mile a minute. The resistance which this mass meets after its fall retards its motion and generates heat.

Hundreds of meteors fall into our atmosphere daily, travelling a thousand times as fast as the waters of Niagara Falls. The resistance to their motion, which our atmosphere offers, heats them white hot, melts them, vaporizes them, burns them up, so that very few of them reach the solid earth in a solid condition.

An iron spile driver, measuring two cubic feet, weighs about half a ton. When it falls sixteen feet upon the end of a spile it is moving at the rate of twenty miles an hour. The energy of this moving mass depends upon both its weight and its velocity, and when its motion is arrested by the spile that energy of motion is largely converted into heat energy, from which both the spile and the spile driver get hot.

A piece of iron may be made red hot by pounding it with a trip hammer.

Count Rumford found, in 1798, while boring cannon in the arsenal at Munich, that the resistance which the iron offered to the motion of the boring tool furnished heat enough to boil water.

Seven hundred and seventy-eight foot pounds of mechanical energy when converted into heat would raise one pound of water (one pint) one degree. This is called the British thermal unit. The spile driver, weighing 1000 pounds, falling 16 feet upon a spile, produces heat enough to raise 1 pint of water 20 degrees.

Here are two binding posts, *a* and *b*, 8 feet apart (Fig. 66), connected by copper wires with

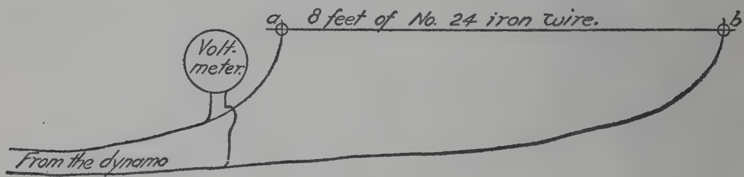


Fig. 66

the dynamo circuit. The volt meter indicates 112 volts of pressure. I will close the circuit by stretching between *a* and *b* 8 feet of No. 24 iron wire. (This wire is about the thickness of a common pin.) The iron wire offers resistance to the flow of the electric current, thereby producing heat — heat enough as you see to make the wire white hot, indeed heat enough to raise it to something over two thousand degrees Fahr., for now you see it has melted.

We will put in a fresh piece of wire and connect also the ammeter in the circuit (Fig. 67). As I close the circuit the needle of the ammeter at first indicates 20 or 30 amperes, but in a second drops to

8 amperes, and remains there a second until the wire melts and falls apart. One hundred and twelve volts

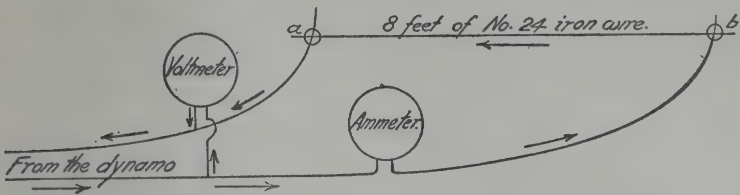


Fig. 67

of electric pressure are able to push 8 amperes of electricity through this wire when hot.

$$\frac{112 \text{ volts}}{14 \text{ ohms}} = 8 \text{ amperes}$$

112 volts x 8 amperes = 896 watts

746 watts = one horse-power

Hence it required about one and one fifth horse-power to melt the wire in a second, and the heat produced was a little less than one British thermal unit, a unit much used by engineers.

> 1 pound raised 1 foot = 1 foot pound
> 550 foot pounds per second = 1 horse-power
> 778 foot pounds (1.4 H.-P.) = 1 B. T. U. (British thermal unit) = heat required to raise 1 pound of water 1° Fahrenheit
> 1 volt x 1 ampere = 1 watt
> 746 watts = 1 horse-power

In order to hold back 112 volts of electric pressure so that not more than eight amperes of electricity

should pass, the iron wire must have offered about 14 ohms of resistance.

The behaviour of the ammeter needle showed that the wire offered very much less resistance when cold than when hot. Indeed eight feet of No. 24 iron wire offers about one and one third ohms resistance when cold, hence heat had increased its resistance to the passage of the electric current tenfold.

This piece of iron wire offered resistance to the flow of the electric current. It offered resistance to the motion of the dynamo. This offered resistance to the steam-engine which drives the dynamo. This caused the governor of the engine to open and pass more steam from the boiler. This reduced the pressure at the steam gauge. This caused the fireman to shovel more coal into the furnace. The heat of the burning coal melts the wire, but it does it only after several changes. First, it is converted into mechanical energy in the steam-engine with great loss — about nine tenths being lost. Second, it is converted into electrical energy by the dynamo, with some loss, and, third, it is conducted to the iron wire and converted back to heat with still further loss. It is evident that the most economical way to heat the wire would be

to take it to the furnace. Yet all electric cooking is done by sending electric current through wires embedded in the walls of the cooking utensils, and it is the most wasteful method of using the energy stored in coal that has yet been devised.

That merely connecting the binding posts *a* and *b* (Fig. 67) by a small piece of wire should throw a load upon the dynamo miles away; should offer resistance to its motion, and make it require 1.18 horse-power more of energy to keep up its speed of revolution, is, indeed, uncanny. I will attempt to

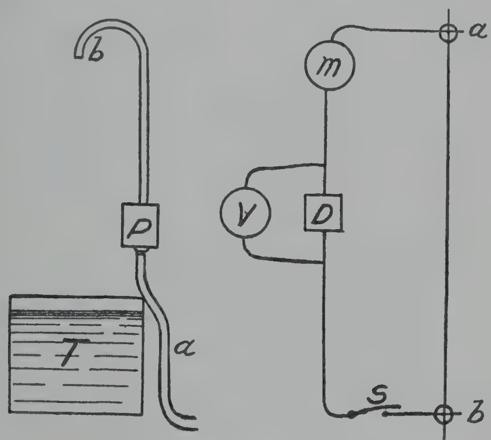


Fig. 68

make it seem more real. At one end of the lecture table I have a rotary pump *P* (Fig. 68) The end of the rubber tube *a*, which leads to the pump

is lying upon the table outside of the tank of water, *T*. While things are in this condition I move the crank which operates the pump with perfect ease. Now while still turning the crank I pick up the tube *a* and drop its free end into the water tank. I cannot now conceal the fact, even if I were disposed to do so, that I must work hard to keep the pump going. The pump itself tells you by its laboured sound that it is working hard, and the stream of water which issues from the pipe *b* tells how much work I am performing. The pump is discharging five and a half pints of water per second, that is 5.5 pounds, and it raises this water 10 feet. Hence I am doing 55 foot pounds of work per second, which requires one tenth of a horse-power. Here is a lad who consents to try the experiment for us. He turns the crank easily while I am holding the tube *a* out of the water, but when I lower it into the water he finds the resistance so great that, tug however much he may, he is unable to keep the pump going.

At the other end of the table I have a small hand dynamo, *D* (Fig. 68), *M* is an ammeter, *V* is a volt meter, *S* is a switch. All the wires are good-sized copper, and offer little resistance, except that stretched between the binding posts *a* and *b*. This

is a piece of fine German silver wire. While the switch is open I turn the crank of the dynamo with perfect ease. A small amount of current is going through the volt meter, but this is too slight to offer any perceptible resistance to the motion of the machine.

Notice that the volt-meter needle moves according to the speed of revolution. If I turn the crank once a second the needle stands at 25 volts. The electric pressure increases or decreases according to whether I rotate the armature faster or slower. Now I will attempt to keep the machine revolving at a constant rate while I close the switch *S*, and surely you must see that I have hard work to do so. The wire *a b* has now become red hot. The volt meter shows 25 volts of pressure, and the ammeter shows 3 amperes of current.

Twenty-five volts $\times$ 3 amperes = 75 watts, which require one tenth of a horse-power (746 watts = 1 horse-power). The lad now takes my place at turning the machine and finds it easy when the switch is open, but I actually overload him by merely closing the switch. Heating the wire red hot requires more energy than he is able to put forth.

I proposed to the president that my lecture close at this point, and that each one in the room have a

chance to *feel* the load which was thrown upon the dynamo each time it was required to heat the wire. I suggested that each person should get a realizing sense of this fact, first by doing the work himself, and second by going home and reflecting upon this hint. When the switch is closed three amperes of electricity pass around the circuit. This increases the magnetism in both the field and the armature of the dynamo, and it requires one tenth of a horse-power more to keep the armature moving within the field against this magnetic pull.

I further desired to announce that during this hour I had delivered to them the second key to the Electrical Show which I had promised a few days ago. The second key is:

Heat (and light) is produced by offering resistance to the flow of the electric current. The first key is the electro-magnet. These two unlock all the mysteries of the show.

The president closed the formal exercises with the facetious remark that I had warned them before the lecture that they must work, so now each would be expected to take a turn at the cranks of the pump and dynamo.

VIII

APPLICATIONS OF ELECTRIC HEATING

THE programme committee decided that each member of the Science Club should busy himself looking for *applications of electric heating* and should consult me freely about the matter. My telephone was kept busy, my laboratory was in great demand, and we were all getting a good deal more education than the school was giving us credit for.

The boys generally came to me in pairs, and each pair having worked up some illustration of heat produced by electricity reported it to the club. These were spread by the secretary in due form upon the minutes of the club and constituted "The Proceedings of the Science Club."

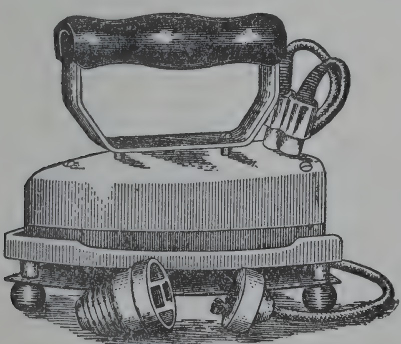


Fig. 69

1. *The Electric Sad Iron* (Fig. 69).—Re-

moving three screws the iron comes apart, revealing a lot of No. 24 German silver wire wound upon a sheet of mica. This is put between other sheets of mica (Fig. 70) and tucked away within the body of the iron. German silver offers about twice the resistance of iron when it is cold, but, at the temperature of the sad iron when in use, there is not much difference between the resistance of the two metals. German silver wire, however, does not rust as iron wire would, and hence it is chosen. German silver is an alloy of copper, zinc, and nickel.

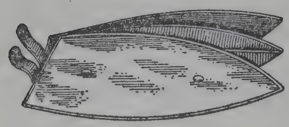


Fig. 70

We put the 112-volt current upon this wire of the iron, and according to the ammeter it passed 4 amperes. Its resistance must therefore have been 28 ohms.

$$\frac{112 \text{ volts}}{28 \text{ ohms}} = 4 \text{ amperes}$$

Electricity costs us about 10 cents per kilowatt hour. That is 10 cents for 1000 watts for an hour, or 1 cent for a hundred watts for an hour, or, on a 100-volt current, 1 cent for an ampere for an hour. It, therefore, costs about 4 cents or, more accurately, 4½ cents an hour to heat this iron.

Persons sometimes carry electric irons with them, when they travel, to iron pocket handkerchiefs and other small articles while stopping at a hotel. Before connecting an iron in a chandelier one must know the voltage used in the building. If the voltage in use in the building is not the same as that stamped upon the iron, it is not safe to connect it. Not knowing this, many persons have had the embarrassment of "blowing a fuse" and extinguishing their own lights, and perhaps those of others in the same building, and very likely also ruining the iron.

Suppose we take for example this iron stamped *110 V; 400 Watts.* (A slight variation of 5 or 10 volts will not injure an iron.) The wire in this iron we found to offer about 28 ohms resistance when hot, and it lets pass 4 amperes. This is about all the current which it is able to carry without melting. Now suppose a 220-volt current is used in the building where it is proposed to connect the iron. This would force through the wire enough current to melt it. The wire was seen to be at a very dull-red heat when examined in a dark room. Its temperature was about nine hundred degrees. At this temperature its resistance is about three times what it is when cold. We estimated by measurements

that the iron contained about twenty-five feet of the wire. The boys then took twenty-five feet of No. 24 German silver wire and stretched it between two nails driven up in the laboratory (Fig. 71, *a b*). The

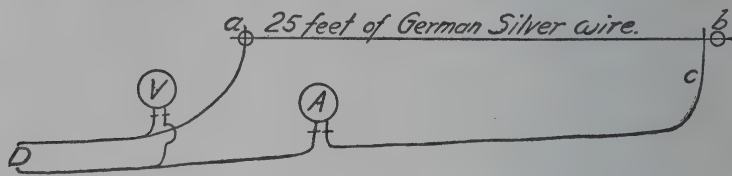


Fig. 71

dynamo current was then sent through this. The end, *c*, of the wire from the dynamo was provided with a metal clip which could be slid along on the German silver wire. Sliding this to the left, and thus shortening the distance on the German silver wire through which the current must pass, increased the amount of current and heated the wire hotter. The resistance decreases as the wire is shortened.

The boys wound this wire upon a piece of asbestos board (Fig. 72), about nine inches square and one eighth of an inch thick, taking care to keep the successive turns half an inch apart. Asbestos paper was wrapped around this. The two ends of the wire were left free for connections. This they called a "hot plate."

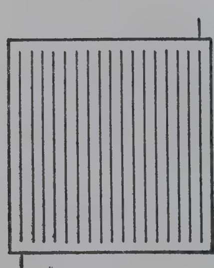


Fig. 72

2. *Electric Hot Plate* (Fig. 73).—This when opened was found to have wire coiled up inside in the same manner as the sad iron. Indeed the sad iron supported bottom side up makes a perfectly good hot plate. The particular hot plate which we examined had a three-point switch which gave three different heats for the plate. (See Fig. 74.) When the switch S is upon the first point the current goes through 112 ohms of resistance and 1 ampere passes:

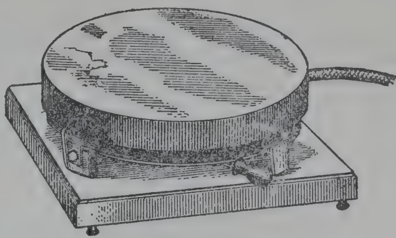


Fig. 73

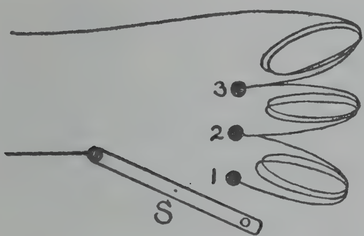


Fig. 74

$$\frac{112 \text{ volts}}{112 \text{ ohms}} = 1 \text{ ampere}$$

This warms the plate slightly — enough to keep food warm which has been already cooked. This costs about one cent an hour.

When the switch is placed upon the

second point the current goes through 56 ohms of resistance and 2 amperes pass.

$$\frac{112 \text{ volts}}{56 \text{ ohms}} = 2 \text{ amperes.}$$

This makes the plate warmer and is adapted to certain cooking processes. It costs about two cents an hour.

When the switch is placed upon the third point the current goes through 28 ohms of resistance and 4 amperes pass.

$$\frac{112 \text{ volts}}{28 \text{ ohms}} = 4 \text{ amperes.}$$

We placed upon this hot plate a basin containing 1 pint of water (equals 1 pound) and heated it from the temperature of the room (68 degrees) to boiling (212 degrees) in 7 minutes and then put an egg in and boiled it 3 minutes. Using 4 amperes for 10 minutes cost two thirds of a cent. If it takes 7 minutes to boil a pint of water it would require 1 hour to boil a gallon upon this hot plate using 4 amperes, or 448 watts. That is,

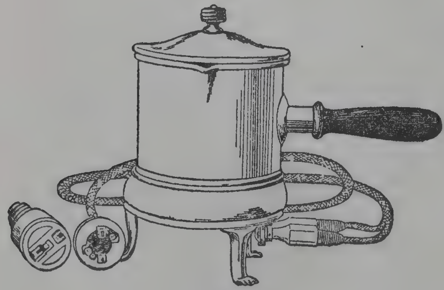


Fig. 75

it costs us about 4.5 cents a gallon to boil water by electricity. The cost is usually put at three and a half cents per gallon, but much depends upon conditions.

3. *Traveller's Cooker* (Fig. 75).—This consists of a hot plate with a covered basin permanently attached to it.

4. *Electric Coffee Percolator* (Fig. 76) consists of a hot plate with a coffee percolator to sit upon it. The coffee percolator might sit upon any other hot plate or this hot plate might serve any other purpose, but people do not seem to think of that.

Fig. 76

5. *Electric Chafing-Dish* (Fig. 77) consists merely of an electric hot plate with a chafing-dish attached. The electric coffee percolators and chafing dishes require from 300 to 600 watts according to size. If used on the 110-

volt current they take about 3 to 6 amperes, and if adapted to the 220-volt current they take from 1½ to 3 amperes, but cost the same to operate in either case. They have connected with them flexible cords and plugs to screw into the lamp sockets.

Fig. 77

6. *Electric Broilers* are merely hot plates, generally corrugated to conduct off the melted fat. One that we examined had a switch for three heats: low, requiring 360 watts — costs 3.6 cents per hour; medium, requiring 600 watts — cost 6 cents per hour; high, requiring 1280 watts — cost 12.8 cents per hour.

7. *Electric Oven.* — This one has double walls to retain the heat and has two large hot plates, one on the bottom and one on the top. It is large enough to hold four loaves of bread. It required 1520 watts for 40 minutes to heat it to the baking temperature and one hour to bake the bread. Hence the cost of the electricity is about 25 cents, about what the bread would cost in the market.

8. *Electric Incubator.* — This is simply a well-ventilated oven warmed by an electric hot plate and automatically controlled so that it keeps a

constant temperature of 103 degrees. Under these conditions chickens hatch from hens' eggs in three weeks. An incubator for 5 dozen eggs was found to take 25 cents' worth of electricity for the whole process of incubation.

9. *Electric Toaster.*—The wire coiled up in sad irons and hot plates becomes hot enough to scorch cloth and paper, and even set fire to them if they come in direct contact. We proved this by opening the iron and touching paper to the wire while it was carrying the current. We also lighted a cigar by touching it to the wire. Electric toasters have the hot German silver wire simply covered by a screen.

10. *Electric Cigar Lighters* (Fig. 78).–The one we examined hung by a flexible cord from the chandelier. It had a small disk on the side which contained a lot of fine wire covered by perforated mica. The wire became red hot when the push button in the handle was pressed. It took half an ampere of 110-volt current, and operated only while the button was pushed. As near as we could calculate it cost .0003 of a cent to light a cigar.

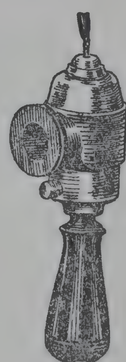


Fig. 78

11. *Electric Curling Iron* (Fig. 79).—One who has flat hair needs no curling iron, but those who have round hair may curl it temporarily, if they

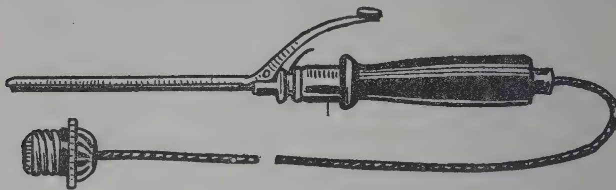


Fig. 79

will unscrew an electric light bulb and screw into its socket the plug of an electric curling iron. The flexible cord contains two wires insulated from each other. One of these wires is attached to the outer shell of the plug, the other wire is attached to the central button of the plug. These make connections with the two separate dynamo wires in the socket. The current comes down one of the wires in the flexible cord, passes through a coil of fine German silver wire inside of the curling iron, and returns by the other wire in the flexible cord. The small wire in the curling iron offers 220 ohms of resistance when hot and passes half an ampere of the 110-volt current.

$$\frac{110 \text{ volts}}{220 \text{ ohms}} = .5 \text{ ampere.}$$

12. *Electric Soldering Irons* (Fig. 80).—Or coppers, as they should be called, are ideal implements for

soldering. They remain continually at the proper temperature and are free from corrosion. They require from 55 to 220 watts. On the 110-volt current they take from one half to two amperes.

Fig. 80

13. *Electric Heating Pad* (Fig. 81). — This consists of resistance wire inside of a pad of soft material. It maintains a temperature of 180 degrees, and is an excellent substitute for a hot water bag. It contains about two hundred and twenty ohms of resistance and requires the same current as a 16-candle-power lamp.

14. *Electric Fuses* (Fig. 82). — Fuses are made of short pieces of wire or thin sheet metal. The metal is an alloy of lead and tin which melts at a low temperature. They derive their name from the fact that they readily fuse or melt. A building is wired in various separate circuits. The size of the copper wires used in each circuit is determined by the amount of current which the circuit is expected to carry.

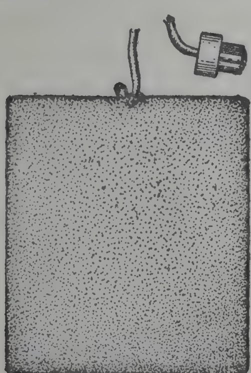


Fig. 81

Each circuit is protected by one or more fuses. These melt and cut off the current whenever too much passes for the copper conductor to carry without getting hot. The fuse wire melts at about six hundred degrees, while the copper will not melt until it reaches nearly two thousand degrees. This temperature is sufficient to set fire to wood, paper, and cloth. When any fuse melts, the current is cut off from all chandeliers, etc., in the particular circuit controlled by the fuse. This produces consternation among people who do not understand the function of a fuse. They become panic-stricken and begin to trample their neighbours to death in the theatre or on the electric train when they hear that a fuse is "blown" (which is the electrician's way of saying that it has melted). Everyone should know that a fuse is a safety device. It is always enclosed in a box lined with sheet iron or asbestos, so that it is impossible for the flash, which occurs when the circuit is broken, to set fire to anything.

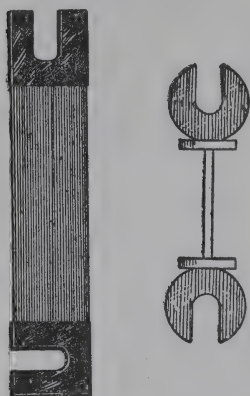


Fig. 82

15. *Electric Gas Lighter* (Fig. 83).—These usu-

ally have two or three small, dry battery cells in the handle. By pushing a button in the handle connection is made between this battery and a short

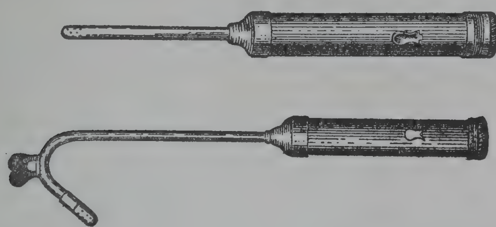


Fig. 83

piece of resistance wire in the tip. This wire gets red hot and lights the gas. It is a surprise to many that we can light illuminating gas without bringing a flame to it, and it is equally surprising that some flames, or at least sparks, may not be able to light the gas. The fact is that it is wholly a matter of *temperature and kind of gas.* Iron heated to dull red will not light the illuminating gas now being furnished in New York City, while iron at a bright red heat will do so. Iron may be hot enough to light illuminating gas but too cool to light gasolene vapour, which requires a dazzling white heat. Iron which is just under the temperature at which it gives any light may set fire to wood and paper. After it has cooled a good deal below that, it will set fire to sulphur, and when it has cooled so that one may

hold it in the hand, it is still hot enough to set fire to phosphorus. The glowing end of a lighted cigar, the spark made by striking flint, or the spark from a spark coil with a feeble battery, all fail to set fire to gasolene vapour, simply because they are not hot enough.

Fresh battery cells must occasionally be put in the handle of the electric gas lighter.

Four facts regarding the resistance of wires it is well to remember:

1. The longer the wire the more resistance it offers to the electric current.

2. The smaller the diameter of the wire the more resistance it offers.

3. Some materials offer more resistance than others, for example, iron about six times as much as copper and German silver about twelve times as much as copper.

4. The common metals offer more resistance when hot than when cold, about double the resistance when heated to five hundred degrees. It is the reverse with carbon, which offers more resistance when cold than when hot. The carbon filament lamp offers about double the resistance when cold as when lighted to full brilliancy.

16. *Electric Flasher* (Fig. 84).—For automatically

flashing electric lights. The one which we examined was constructed according to the plan shown in Fig. 85. The lighting circuit is brought to the binding posts *b* and *c*. A small insulated wire of high resistance connects *b* and *c*, being wound around the metal bar *a b*. The resistance of this wire, when added to that of lamps, permits not more than one fifth of an ampere to pass, and this warms the wire slightly. The bar *a b* is composed of two strips of metal, brass above and iron below. Heat expands brass more than iron. The result is that when the current is turned on, the bar begins to curve downward until presently it touches the metal base of *c*. Then the full current required to light the lamps which are in circuit passes. While the circuit is closed through the large metal strips not enough passes through the fine wire to warm it. On cooling, *a b* curves upward and breaks the connection with *c*, and now the current begins again to warm up the small wire.

Fig. 84

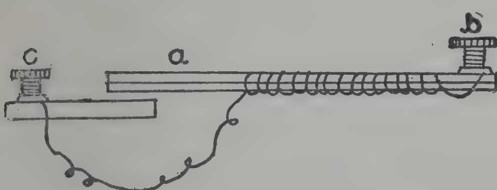


Fig. 85

The flasher that we examined was adapted to operate: one 32-candle-power lamp; or two 16-candle-power lamps; or four 8-candle-power lamps, on a one ampere circuit of 110-volt pressure.

Let us see what would happen if it were connected either with a current of higher voltage or a circuit of more lamps. Suppose we have a 32-candle-power carbon filament lamp in circuit. This requires one ampere to light it. Its resistance when hot is 110 ohms.

$$\frac{110 \text{ volts}}{110 \text{ ohms}} = 1 \text{ ampere.}$$

When cold its resistance is about double or 220 ohms. The German silver wire of the electric flasher offers 330 ohms of resistance, and together they make 550 ohms. Thus the current is cut down to .2 ampere.

$$\frac{110 \text{ volts}}{330 + 220 \text{ ohms}} = .2 \text{ ampere}$$

Suppose now we should undertake to use the same flasher and the same lamp on a 220-volt current. This might push more current through than the small wire could carry. It might melt, or its insulation might burn off before *a* made contact with *b*; if not the lamp would certainly burn out after the contact. If we undertook to operate with this flasher several 32-candle-power lamps

instead of one upon the 110-volt circuit, the result would be the same, for in that case the resistance would be reduced and, therefore, a greater current would pass than the wire could carry without undue heating.

The boys were at first troubled to see how increasing the number of lamps in a circuit would decrease the resistance in that circuit. Fig. 86

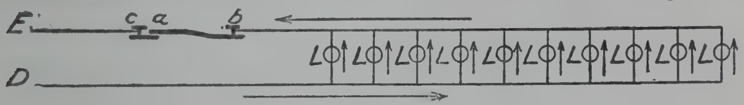


Fig. 86

was drawn to explain the matter. The lamps *l*, *l*, *l*, etc., are connected *in parallel.* Each lamp makes an independent connection from one feed wire to the other. The flasher *a* acts as a switch to close the circuit for the whole.

Now if we think of these wires as pipes to conduct water we would say that water flows from *D* to *E* through ten pipes more readily than through one. It would meet with only one tenth as much resistance. The result would be the same, if we should substitute for the ten pipes one pipe ten times as large in cross section. So it is with wires which are conducting electricity. Introduce two in parallel, and you allow twice as much current to pass by reducing the resistance to one half. Ten parallel

conductors reduce the resistance to one tenth and allow ten times as much current to pass.

It is to be noticed that this flasher is an automatic switch which is opened or closed according to temperature. Remove the fine wire from *a* and we have precisely the device which regulated the temperature in our electric incubator. Suppose the "thermostat" (as it is called in that case) is placed within the egg chamber which is to be kept at 103 degrees. A screw in the metal strip *c* underneath

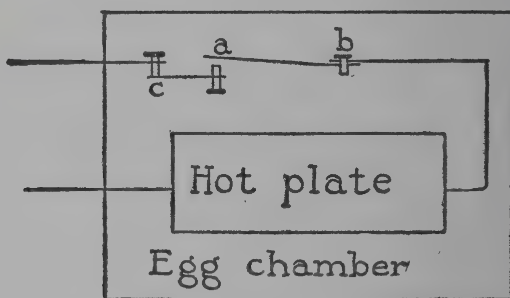


Fig. 87

the end of *a* may be set so that it will normally touch *a*. Suppose now the brass strip is underneath the strip of iron in *a*. As the hot plate warms up the egg chamber, the brass will expand more than the iron, and the bar will curve upward and break the connection with *c*. As soon as the current stops the temperature of the chamber begins to fall, and the bar curves downward again until connection

is made. This device is capable of adjustment so as to keep the temperature constantly at 103 degrees or any other desired degree. The device is in use for scores of different purposes, including the regulation of temperature in school rooms.

17. *Electric Car Heaters.*—Ten or fifteen years ago there were no heated street cars in New York City. Now they are all heated by electricity and their maximum and minimum temperatures are regulated by law. The resistance wire may be seen in coils underneath the car seats. Electric street cars usually operate on a 500 or 600-volt current. The amount of current used for heating varies from 2 to 12 amperes. Perhaps 3 amperes may be taken as an average.

$$500\ V \times 3a = 1500\ w = 1\tfrac{1}{2} \text{ kilowatts.}$$

It costs the large electric railway companies about 1.5 cents per kilowatt hour to generate their supply of current. Eighteen hours is considered a car day.

$$1\tfrac{1}{2} \text{ kilowatts} \times 18 \text{ hours} = 27 \text{ kilowatt hours.}$$

27 kilowatt hours at 1.5 cents = 40 cents per car day.

18. *Heating Apartments by Electricity.*—For heating apartments by electricity the same sort of apparatus is used as that already described for heating cars. A family of four adults, living in an eight-room apartment with at least 120 cubic

feet of fresh air admitted per minute, will use on an average ten amperes of the 110-volt current. The cost will be about two dollars and fifty cents per day or seventy-five dollars per month. Although this is as much as the entire rental of a perfectly comfortable apartment, the novelty and the convenience attract tenants and the extra cost of rent does not deter them.

19. *Electric Bedroom Heater.*—One of the boys constructed a heater for his own room as follows: He procured a box eight inches deep by eighteen inches square on the bottom. This he lined with asbestos paper. He then stood it upon its side and arranged four incandescent light sockets as shown in Fig. 88. These were connected by a flexible cord to a plug which he could insert in place of a lamp in the chandelier. He placed this heater on the floor underneath the window and usually had 16-candle-power lamps in the sockets. He claimed that it was a jolly foot warmer and kept the room comfortable without other heat. He turned on

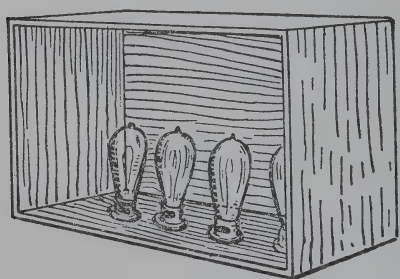


Fig. 88

from one to four lamps according to his need and replaced the 16-candle-power lamps by 32-candle-power lamps when the weather was extremely cold. I remarked that he must have light along with heat by this arrangement, and I should think that might be objectionable when he desired to sleep at night. He said that he always turned it off, and opened the window at night, always preferring a cold room to sleep in.

20. *Cooking with Incandescent Lamps.* — This piece of apparatus was devised by the boys and used in my laboratory. A sheet iron basin *a*, was inverted over four 16-candle-power incandescent lamps, shown in elevation by Fig. 89, and shown in plan by Fig.

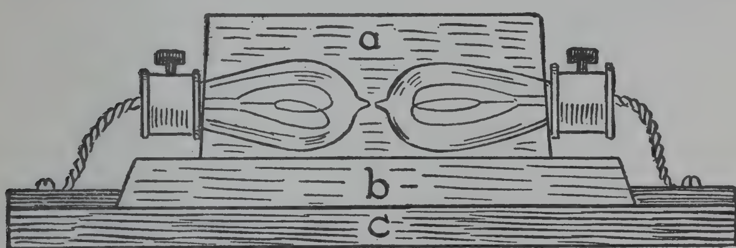


Fig. 89

90. The sides of the basin were cut so as to admit the glass globes of the lamps, but the sockets and keys were outside, so that it was convenient to turn on and off the lamps separately, thus using one half to two amperes of current, as desired. This rested

upon another basin, *b*. Basin *b* was covered with asbestos for the lamps to lie on and the whole was attached to a board base, *c*. A flexible cord and plug allowed us to attach this to the chandelier. A pint of water was boiled upon this stove in fifteen minutes, and refreshments have been served hot from it repeatedly.

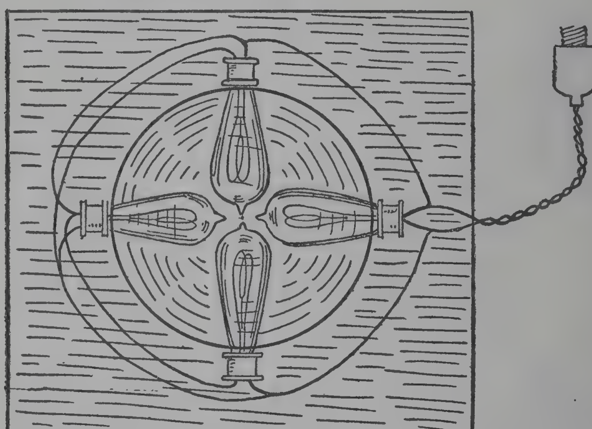


Fig. 90

21. *Electric Fireless Cooker.* — There are five indictments against ordinary cooking processes.

1. They heat the house in summer.

2. They convert what would be pleasant flavours in the food into noxious odours about the house.

3. They cannot be controlled with regard to time and temperature as scientific experiments should be.

4. They confine the cook too closely and are not sufficiently automatic.

5. They are wasteful of fuel.

It would seem that electricity might enable us to cure most of these evils. To be sure the production of heat by electricity is wasteful of fuel, and it seems doubtful how the account will balance regarding the fifth item. But the remaining four items furnish a very hopeful field for research. I use the last word advisedly, and think it is just as applicable to high school boys as to university students. After experimenting awhile the boys and I concluded to give a dinner party in the laboratory and invite a few friends to test the results of our cooking.

We procured a cylinder of magnesia such as is used for covering large steam-pipes. This was inverted over our electric stove which was illustrated in Fig. 89. The magnesia was cut at the bottom, so as to give access to the key sockets of the lamps, (Fig. 91). First upon the electric stove was placed a covered dish containing a roast of lamb. Above this was another dish containing a vegetable, and upon the top of that was a pudding. A flat piece of magnesia was used as a cover to the whole. Through a hole in this was suspended a thermometer.

This "fireless cooker" was sitting in the centre of the dinner table when the guests gathered around it. We had these problems for investigation:

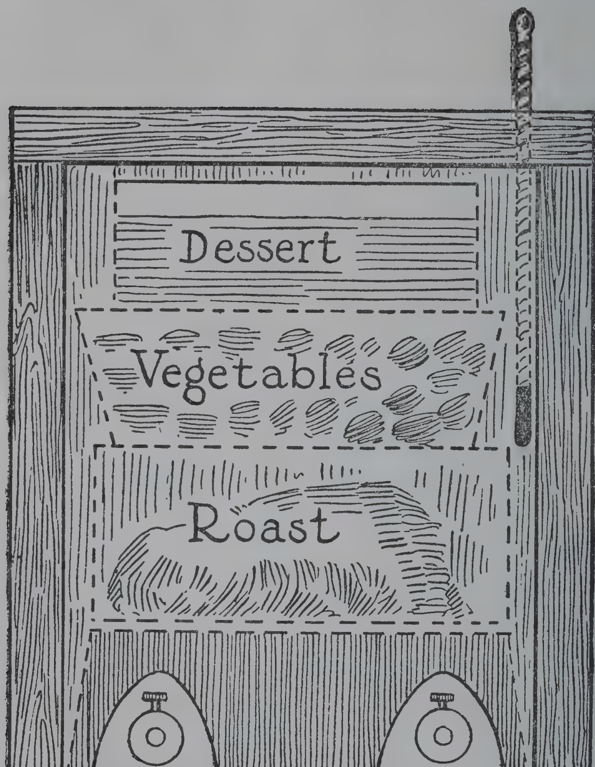


Fig. 91

1. Will this cooker heat the house in summer?

All testified that they did not know that there was any heat about it until they laid their hands upon it, and then they found it only very slightly warm.

2. Is there any smell of cooking here? The process has been carried on from start to finish right on this table.

All agreed that no smell could be detected.

I then turned off the electric current which had been running until now and served the meat and vegetable, leaving the pudding inside to be kept warm by the hot walls of the cooker.

3. Regarding the control of the process: we were using 32-candle-power lamps, which gave us a variable current, from 0 to 4 amperes, and a watch and a thermometer. We had control, but as yet lacked knowledge of how it should be used. In the present case we had arbitrarily decided to begin with temperature of 400 degrees, continue it for 20 minutes, then turn off all the electric current, and let the temperature fall gradually. This had been done at our convenience in the morning before school. At a quarter before twelve we had found the temperature at 200 degrees, and turned on all the current, and now, at five minutes past twelve o'clock, all testified that the lamb was particularly good—neither too well done nor undercooked, and that its flavour was better than usual.

As for economy of fuel, we find at least that we get better results from incandescent lamps than

from hot plates used in the same apparatus, and the electric equipment enables us to put the heat exactly where it is needed and nowhere else.

22. *Incandescent Lamp.*—We feel quite justified in putting the incandescent lamp under the heading, *Applications of Electric Heating*, since the electric lamps in general use convert 96 per cent. of the electric energy into heat and only 4 per cent. into light.

They were originally made by introducing a short piece of fine wire into the circuit, choosing the kind of wire, its diameter, and its length so as to make the proper relation between resistance and voltage, in order that enough current might pass to make it white hot, but not quite melt it. Platinum wire was first chosen because it would stand the highest heat without melting and without rusting.

We will pass our 112-volt current through 9 feet of the No. 24 iron wire. The wire is heated to bright red, but does not melt as it did when we used 8 feet in a former experiment. The increased length has added resistance, and, as you see by the ammeter, cut the current down from 8 to 7.5 amperes. I will now darken the room and you find that it is giving light enough to read by. But you notice that the light is growing dimmer, its colour is growing

redder, and the ammeter indicates that less current is passing. I will cut off the current and let you examine the wire and you notice that a crust has formed upon it. This is due to the oxygen of the air which unites with the iron, forming iron rust. Iron rust does not conduct electricity. We have converted No. 24 iron wire into a wire of smaller diameter with a sheath of iron rust around it. We might prevent the rusting by putting the wire in a glass globe and exhausting the air from it.

I have here a piece of No. 24 platinum wire which has about the same resistance as iron wire when cold, but you notice that I may use a very much shorter length than I did of the iron wire because it will endure a very much higher heat without melting. Reducing the length would reduce the resistance, but reducing the resistance would allow more current to pass. If more current should pass it would make the wire hotter, and raising the temperature would increase the resistance, which would cut down the current, etc. By sliding the clip *c* (Fig. 92), along, I finally reach a point where conditions balance so that I get a very brilliant light, dangerously near the fusing point of the platinum which is three thousand degrees above the boiling point of water.

In 1879 Mr. Thomas A. Edison literally searched the whole world for something better than platinum for the filament of an incandescent lamp. He finally decided upon charred threads of a bamboo

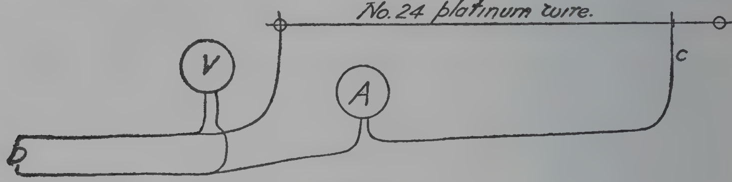


Fig. 92

which he found in Japan. No research was ever more timely than this. Whereas there was practically no electric lighting before 1880, soon after that there began a phenomenal demand for carbon filament lamps. In 1890, 800,000 of these lamps were manufactured in the United States. In 1900 the number had risen to 25,000,000. In 1909 central stations were supplying electric current to 41,807,944 incandescent electric lights. By far the greatest number are still made with carbon filaments.

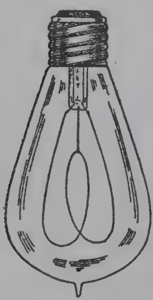


Fig. 93

We examined an ordinary 110-volt 16-candle-power carbon filament lamp, (Fig. 93). As near as we could estimate, its filament measured about eight inches in length. We broke open the bulb of this lamp by laying it upon the table and tapping

it with a board. The bulb broke with rather a loud noise and the brittle carbon filament broke into many pieces. We found one of these pieces and measured its diameter with a wire gauge, (Fig. 94). It was the same size as No. 33 wire, which we also found by the wire gauge was the size of No. 90 sewing cotton. The diameter of No. 33 wire was given upon the wire gauge as .007 inch. When lighted, the filament of this lamp had looked to be about the size of No. 18 wire, which has a diameter of .04. That is, the filament when lighted looked six times as thick as it really was. Those who use sewing cotton learn quickly to know the size of the thread by its number. So those who have much to do with wire easily learn the system of designating sizes by numbers. Here are some selected figures easy to remember. A trolley wire is about one third of an inch in diameter. It is designated as No. O. Notice in the following table that as the numbers rise by six the diameters are divided by two. Notice also that as the diameters diminish by two the resistance increases by four.

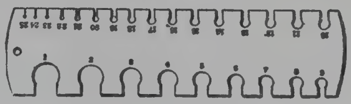


Fig. 94

TABLE OF RESISTANCE OF COPPER WIRES

Nos.	*Diameter*	*Resistance*	
0	.32 inch	10560	feet to the ohm
6	.16 "	2640	" " " "
12	.08 "	660	" " " "
18	.04 "	165	" " " "
24	.02 "	40	" " " "
30	.01 "	10	" " " "
36	.005 "	2.5	" " " "
42	.003 "	1	" " " "

10,560 feet equal two miles.

Number 36 is the wire used upon the spools of telegraph receivers. They offer 75 ohms of resistance and therefore contain 30 feet of wire (30 x 2.5 = 75). These resistances are for ordinary school room temperatures.

Since iron has six times, and German silver twelve times the resistance of copper, divide the figures of the third column by six, and the table will answer for iron wire, or divide those figures by twelve and the table may be used for German silver wire, thus:

		Number Feet to the Ohm		
Nos.	*Diameter*	*Copper*	*Iron*	*German Silver*
0	.32 inch	10560	1760	880
6	.16 "	2640	440	220
12	.08 "	660	110	55
18	.04 "	165	27	14

		Number Feet to the Ohm		
Nos.	*Diameter*	*Copper*	*Iron*	*German Silver*
24	.02 inch	40	6	32 inch
30	.01 "	10	1.5	8 "
36	.005 "	2.5	.45	2 "
42	.003 "	1	2 inch	1 "

These figures are not exact, but useful.

We procured a string of eight small lamps (Fig. 95), such as are used in lighting Christmas trees. Each was marked 14 volt, 2-candle-power. The carbon filament of each was about one inch long and apparently the same diameter as that of the 16-candle-power lamp. When the 110-volt current was sent through the group of eight connected in series they seemed to give about the same light as the single 16-candle-power lamp. It is as though the filament of the 16-candle-power lamp had been cut into eight pieces, and distributed through eight small lamps. We introduced an ammeter into the circuit and found that half an ampere of electricity passed through the single 16-candle-power lamp — and half an ampere likewise passed through the group of eight 2-candle-power lamps.

Fig. 95

The 110-volt current can push an ampere of electricity through eight inches of carbon thread seven thousandths of an inch in diameter, and when this happens the filament gets hot enough to give out as much light as sixteen standard candles. In the place of the 16-candle-power lamp, we put a 32-candle-power 110-volt lamp. The ammeter indicated one ampere. The carbon filament was larger (No. 30, diameter = .01 inch), so as to allow more current to pass. An 8-candle-power 110-volt lamp was substituted; one quarter of an ampere passed. A 4-candle-power 110-volt lamp was used; one eighth of an ampere passed. A 100-candle-power 110-volt lamp was substituted; three amperes of current passed through it. In all these cases the lamps which passed the larger current had the larger filaments. A little practice would enable one to distinguish between these lamps without labels by examining their filaments. Among these 110-volt lamps, it is to be noted that the amount of light which they give is proportional to the amount of current which they pass. And it is convenient to remember that one ampere of electricity for one hour costs about one cent.

We introduced into the socket a "Hylo" lamp (Fig. 96). The filament, *A*, took half an ampere of

electricity, gave 16-candle-power of light, and cost half a cent an hour. When the lamp was turned in its socket the current was switched off of the filament *A*, and on to the filament *a*. This took .03 of an ampere, gave one candle-power of light, and cost .03 of a cent an hour, or at the rate of about $3.00 a year, burning continuously day and night.

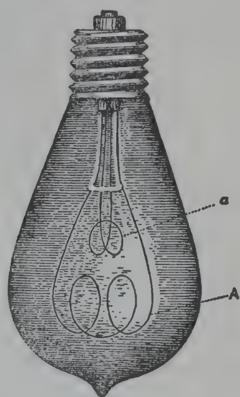


Fig. 96

The uses of such a lamp are apparent in rooms which have no daylight. However, a wall switch at the entrance of such a room, making it easy to throw on and off the light entirely, seems to be a more satisfactory arrangement. One of the boys connected a wattmeter in the circuit with a hylo lamp and found that the small filament did not pass current enough to move the armature of the wattmeter. Hence that may be burned alone without affecting the consumer's bills.

We took a 16-candle-power 220-volt lamp, and lighted it by a 220-volt current. The meter showed that it allowed only one quarter of an ampere to pass. The filament was very much smaller than that in the 110-volt, 16-candle-power lamp. The

pressure was twice as great as before, but the resistance was four times as great, and hence only half as much current passed. We find that it costs just as much to generate one quarter of an ampere at 220-volt pressure as it does to generate half an ampere at 110-volt pressure.

We must, of course, pay for electricity according to the cost of producing it. To produce .5 ampere at 110-volt pressure costs the same as one ampere at 55-volt pressure, or .25 amperes at 220 volts. It will be noticed that the products of the two factors in each case are the same. The product of an ampere multiplied by a volt is a watt. In each of the above three cases the amount of electrical energy is 55 watts. This will produce a definite quantity of light — about 16 candle-power when the carbon filament is used, and this quantity does not vary as either volts or amperes, but as the product of these, namely, watts.

Each of these lamps is called a 55-watt lamp, and, since they each give 16 candle-power of light, a carbon filament lamp gives one candle-power of light for three and a half watts of electricity. Electricity for lighting purposes usually costs *10 cents per kilowatt hour*, that is, 10 cents for 1000 watts for one hour, or one cent for 100 watts for

one hour. Hence a 55-watt lamp costs a trifle more than half a cent for one hour, or exactly .55 cents, and a 32-candle-power lamp costs 1.1 cents per hour.

We introduced into the socket a 48-candle-power 110-volt tungsten lamp (Fig. 97), and turned on the 110-volt current. The ammeter showed 55 ampere. Hence the lamp is a 60-watt lamp, and requires one and a quarter watts per candle-power. That is, the metal tungsten is nearly three times as efficient as carbon for producing light from electricity.

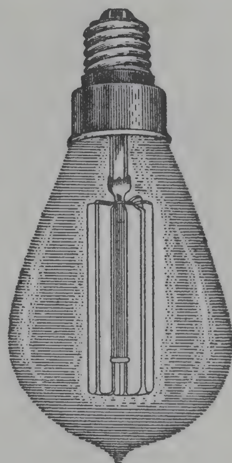


Fig. 97

With pincers we broke off the tip of a 32-candle-power carbon filament lamp, making a small hole in the large end of the bulb. The air rushed in. We then put the lamp in the socket and turned on the current. The carbon filament glowed as usual, and slowly burned up, growing smaller as it did so. The ammeter which was in circuit showed that the current, which was one ampere at the beginning, grew steadily less as the filament grew smaller, until finally when it was about one quarter of an ampere, the circuit was broken by the filament

burning in two. We removed the lamp from the socket and with a dropper tube introduced a little lime water, and shook it to absorb any gas which might have been formed in there. It became milky white, as it always does when introduced where carbon has been burned. This would be a sufficient proof that the filament was made of carbon, if we did not already know it. The air is exhausted from these bulbs to prevent the carbon filament from burning up.

The carbon filament lamps were, as has been said, the invention of Mr. Thomas A. Edison in 1879. Such a statement must, however, be qualified by the assertion that this, like nearly all invention, was but the consummation of a long line of researches made by many men for many years. The early filaments were made of bamboo thread, charred, but now they are drawn like spider's web out of a sticky liquid and carbonized at a high temperature. They are attached in the lamp to short pieces of platinum wire which are sealed through the glass walls of the bulb. One wire connects with the brass collar of the bulb, and the other with the central piece of brass at the base of the bulb. We dissected a socket and found that when the lamp is placed in the socket, the collar

of the lamp is screwed into the collar of the socket, and the base of the lamp comes in contact with a brass spring in the bottom of the socket (Fig. 98). The spring is connected with one copper wire bringing electricity from the dynamo. The collar is connected with the other wire from the dynamo. This connection is made and broken by turning the key of the socket. The wires are made of copper since copper is a particularly good conductor of electricity. No electricity can flow unless this circuit is complete. Socket keys and wall switches make or close gaps in this circuit. No copper wires for carrying electric-lighting current are smaller than No. 12, which has a diameter of .08 or about one twelfth of an inch. The intention is to have as little resistance to the current as possible, except in the filament of the lamp itself. There resistance is purposely introduced in order to convert electricity into light, light without heat if that were possible, but since that has not yet been found possible, heat for the sake of the accompanying light. Unhappily only 4 per cent. of the electrical energy goes into light and 96 per cent. goes into useless, or even

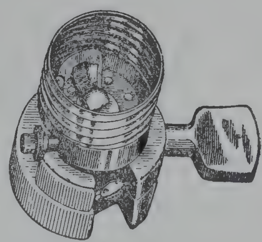


Fig. 98

harmful, heat. The tungsten lamps, which are now coming into use, are nearly three times as efficient in the production of light as are the carbon filament lamps. The dynamo exerts its entire pressure upon the lamp and furnishes current as follows:

A dynamo of 110-volt pressure gives:

1 ampere = 110 watts, through a 32-candle-power lamp, cost one cent an hour, or

.5 ampere = 55 watts, through a 16-candle-power lamp, cost half a cent an hour, or

.25 ampere = 27½ watts, through an 8-candle-power lamp, cost a quarter of a cent an hour.

A dynamo of 220-volt pressure gives:

.5 ampere = 110 watts, through a 32-candle-power lamp, cost one cent an hour, or

.25 ampere = 55 watts, through a 16-candle-power-lamp, cost half a cent an hour, or

.125 ampere = 27½ watts, through an 8-candle-power lamp, cost a quarter of a cent an hour.

The carbon filament lamps, barring accidents, have a natural life varying from 600 to 1000 hours of actual incandescence. At the end of that period the filament has become so thin that it will fall apart by ordinary usage. It is never profitable, however, to use them for their whole lifetime. The lamp gradually volatilizes carbon and deposits

it upon the inner walls of the bulb, producing a smoky appearance and shutting off light. As the filament grows thinner by this process, it offers greater resistance to the current, and as the amount of current grows less the proportion of light to current grows rapidly less, so that at last instead of paying for 3.5 watts of electricity per candle-power of light one must pay for perhaps seven or eight watts per candle-power. We pay fifteen cents apiece for 16-candle-power lamps, and it is economy to renew them about twice a year, if they are burned, say three hours a day, or a little over five hundred hours. It is interesting to note that when a direct current is used the evaporation from the carbon filament always takes place at the negative end alone, that is, the end from which the current is leaving the lamp. If an alternating current is used the evaporation goes on from all parts of the filament alike. This is a case of evaporation from the solid state. Carbon does not boil below 6,000 degrees, and the filament reaches about 2,450 degrees.

Tantalum, tungsten, and osmium lamps have metal filaments. These metals are better conductors than carbon but unlike carbon their resistance increases as their temperature rises, and their special virtue is that they are capable of enduring

an extremely high temperature without melting. The wire used in some of these filaments is as small as .002 of an inch, or No. 44. In order to furnish sufficient resistance to prevent the 110-volt current from melting, they often have a length exceeding two feet. This is laced back and forth within the small bulb. At the temperature of bright incandescence their resistance may be increased as much as fivefold and sometimes becomes about ten ohms to the inch. Like all metals they are more brittle when cold than hot. Hence when cleaning such lamps it is advisable to turn on the current to avoid breaking the filament by jarring. Filaments which are too fragile to endure the jar of ordinary railway travel, when cold, have gone through railway wrecks safely when lighted.

It is a general rule that good conductors of electricity grow more resistant as the temperature rises while non-conductors resist less as the temperature rises. Hence the insulating material which is used to cover copper wires fails to protect if highly heated.

If a 110-volt lamp is put into a 220-volt circuit, one might expect that the lamp would burn out without doing further damage to the circuit, but this is not the case. As the filament approaches its melting point, 6000 degrees, it becomes so good

a conductor that it carries current enough to melt a fifteen ampere fuse. It is, therefore, the fuse that protects the circuit and not the burning out of the lamp. The bulb containing the highly heated carbon vapour would conduct the current as an arc lamp does.

23. *Arc Lamp.*—We fastened two electric light carbons to the ends of copper wires connected for the 110-volt current. A rheostat, *R* (Fig. 99), in circuit, was set at 6.5 ohms. One lower carbon was fastened into a clamp, and the other was touched to it, and then drawn away about three-eighths of an inch. A very brilliant light was produced. Probably about 1800 candle-power. The ammeter *A* showed 10 amperes, and the volt meter V showed 45 volts. 45 volts x 10 amperes= 450 watts, 1800 candle-power, 25 watts per candle-power.

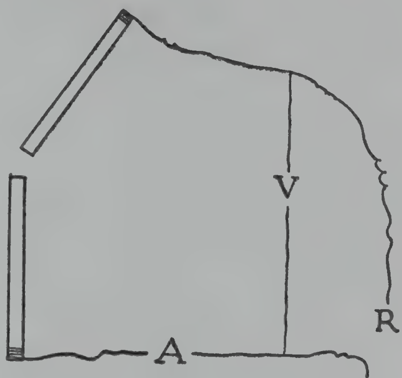


Fig. 99

The arc light is the cheapest of all lights but is too dazzlingly bright for household purposes. It

is used for outdoor lighting chiefly, and particularly for large search-lights. The temperature is over 6000 degrees, which boils the carbon and fills the gap between the two pencils with a stream of carbon vapour. This conducts the current like the filament in an incandescent lamp. The air gap between the carbon pencils would have a resistance of many thousand ohms if it were not for the presence of the carbon vapour. The hot carbon vapour reduces the resistance of this space to 4.5 ohms.

$$\frac{45 \text{ volts}}{4.5 \text{ ohms}} = 10 \text{ amperes.}$$

or

$$\frac{110 \text{ volts}}{6.5 + 4.5 \text{ ohms}} = 10 \text{ amperes.}$$

The carbon pencils account for part of this resistance — not more than a third of an ohm however.

It is evident that arc lamps in use must have an automatic mechanism which shall permit the carbons to touch whenever the current is not passing, but which shall draw them apart to the proper distance after the carbon vapour has been formed, or, as we say, after the arc has been established. This mechanism is nothing else than electro-magnets which are operated by the lighting circuit itself. It may require thoughtful examination to

recognize these as electro-magnets, in every case, but that is what they are. Sometimes they are coils of wire, which do not have iron cores and armatures separate to be sure — but nevertheless they have both of these united in one movable rod, and they produce magnetic fields.

Suppose I pass an electric current around this coil *A* (Fig. 100). The region about the coil becomes a magnetic field with its north pole situated at a point in space, say N. The influence of this field causes the iron rod to become a magnet with its south pole uppermost, and if the current is strong enough, and the field which it produces is strong enough, it will lift the iron rod up into the coil. By varying the strength of the current you see I may make this rod dance up and down in space touching nothing — a veritable ghost dance.

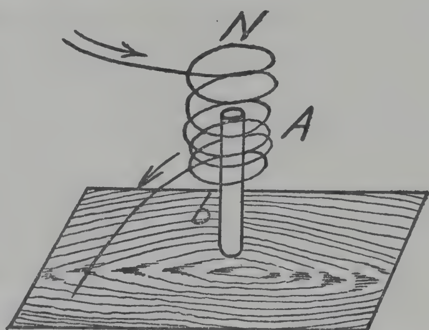


Fig. 100

It may be pettifogging to say that the upper portion of this iron rod is the core of the magnetic field, and its lower portion is the armature. Yet

this is right, and pettifogging may be right when it is the only way to bring out the fact.

Our great study now is to produce light without heat, or at least to come as near to it as the firefly does. The firefly gives 98 per cent. light and two per cent. heat. The arc lamp gives 12 per cent. light and 88 per cent. heat. The carbon filament gives 4 per cent. light and 96 per cent. heat. When we have made considerable progress in that direction we shall take electric lamps out of the chapter on electric heating and form a new chapter on electric lighting.

One might expect that a rod made of carbon would quickly burn up, particularly when raised to the exceeding high temperature of the electric arc. While it is true that carbon in the form of charcoal burns so readily that it is used instead of kindlings for lighting a fire, carbon in the form of graphite in our so-called "lead" pencils and carbon as it is prepared for electric light pencils burns only very slowly even at exceedingly high temperatures. The carbon rods used in arc lamps endure a temperature of over 6000 degrees, without losing more than one inch an hour, and half of that is simply volatilized — not burned.

One of the most interesting improvements ever made in the arc light is that of enclosing the arc

in an inner glass globe. This globe is closed air-tight below with a small opening above. When the arc is formed the oxygen of the air in the inner globe is soon consumed and then combustion is no longer possible. We illustrated this by an experiment. An ordinary cork was chosen to fit the large end of an argand lamp chimney and through a hole in this was passed one of the carbon rods (Fig. 101). A metal clamp made connections between this carbon and the negative wire from the dynamo. The other carbon, attached by a clamp to the positive wire, was thrust down into the upper end of the chimney until it touched the negative carbon, and then drawn upward a short distance, drawing an arc, as we say. This soon makes an atmosphere within the chimney where combustion cannot go on for want of oxygen. The arc, however, continues to glow as in the open air, and the carbons may be drawn further apart than in the open air without breaking the arc, hence more of the external resistance may be cut out and a higher voltage put upon the lamp.

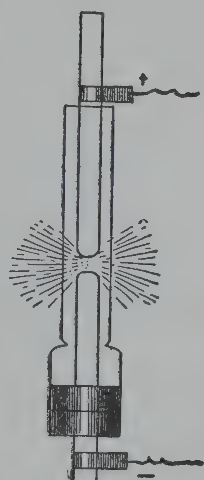


Fig. 101

Carbons which burn out in a single night if used in open arc lamps last two weeks in enclosed arc lamps.

The lower carbon, when removed from the lamp chimney of the last experiment, served as a lead pencil to write on paper. The positive carbon would not make a mark on paper. In all arc lamps carbon is distilled from the positive pencil, condensing upon the negative pencil as graphite, which is the material used in making "lead" pencils. They are called "lead" pencils because they were originally made of lead, but now they are made of graphite which is mined from the earth.

As soon as the arc is broken it becomes evident that the positive carbon has been heated much the hotter of the two, a fact that could not be detected while it was lighted because of the dazzling brightness of the arc. The negative carbon turns black almost immediately, while the positive carbon remains at a bright red heat for some time.

This fact needs to be borne in mind when adjusting arc light carbons in search-lights, stereopticons, and all like apparatus in which the light must be placed at the focus of a lens. That is, it is necessary to know from what point the light really comes and it is necessary to have some adjusting device

to keep this point continually at the focus of the lens.

24. *Search-Light.*— (Fig. 102). This is simply an arc lamp with reflectors behind it and lenses in front of it. The whole apparatus is pivoted so as to be easily made to shine in any direction. The function of the lenses and the reflectors is to collect stray rays of light and send them all out in the same direction. This is shown in Fig. 103 where for simplicity the lens is represented as a single piece. *L* represents a point of light which will naturally send its rays out in all directions as the radii of a sphere; *m*, *m*, *m* represents a bright reflecting surface which is given that peculiar curve called a parabola. It has the unique faculty of reflecting in a parallel direction all the rays which may fall upon it from *L*, so long as *L* is kept at that particular point called the focus, *a b* is a lens of glass which has that peculiar curve that enables it to bend all rays which fall upon it from *L*, so that they may pass out parallel.

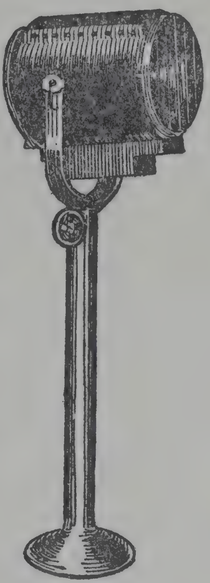


Fig. 102

25. *Stereopticon.* — This also has the necessary

devices to gather the rays of the arc lamp and send them forth parallel, and in addition it has a series

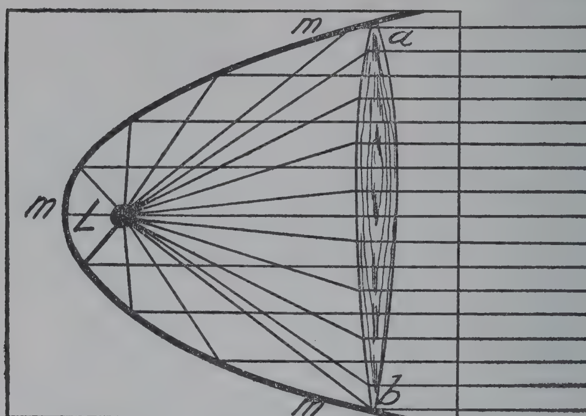


Fig. 103

of lenses which produce upon a distant screen an enlarged picture of any transparent object held in these parallel rays.

26. *Burglar's Flash-Light.*—There are many forms of this. The one we examined is represented in Fig. 104. We unscrewed a metal ring at the left-hand end and found, first a glass lens and behind that a miniature electric light, requiring three volts and half an ampere. We

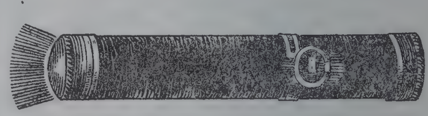


Fig. 104

knew, therefore, that it must be supplied with two cells, since one cell may give not more than 1.5 volts. We also knew that it would only be used to *flash* a

light, since if dry cells are required to furnish half an ampere continuously they soon run down. Behind the lamp there was a bright metal reflector — the lens and reflector are fairly well represented in Fig. 103. The filament of the lamp is connected with two small battery cells in the handle. These may be removed and replaced by new ones by unscrewing a cap at the right-hand end. The circuit is closed by a metal spring on the side of the tube, which acts as a push button. It is situated where it may be conveniently pressed by the thumb. The small batteries necessarily have a short life and must be replaced quite frequently. Being a special thing they cost nearly twice what the regular dry cell does.

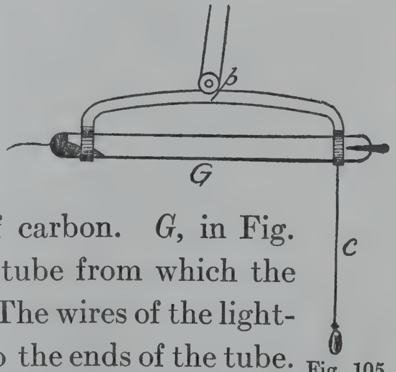


Fig. 105

27. *Mercury Vapour Lamp.*—This is an interesting variety of arc light in which the vapour of mercury takes the place of the vapour of carbon. *G*, in Fig. 105, represents a glass tube from which the air has been exhausted. The wires of the lighting circuit are fused into the ends of the tube. At one end, and in contact with one of these wires, is a small pool of mercury. By pulling the cord *c* the tube is tilted on the pivot *p*, so that a stream of

mercury flows along the whole length of the tube and closes the electric circuit. When the tube falls back into its normal position, as represented in the figure, the electric arc persists upon the mercury vapour. Incandescent mercury vapour gives light strong in green, blue, and violet, but deficient in red and yellow. It, therefore, gives nothing its natural appearance but casts a ghastly hue over everything.

This lamp was invented in 1902, by Peter Cooper-Hewitt, grandson of the founder of Cooper Union in New York City.

It gives a very suitable light for making photographic prints, and is much used for that. This lamp operates upon the 110-volt circuit. It is the longest step yet taken toward getting light without heat, but perhaps shows what we must expect when we reach that goal, namely, unsatisfactory colour values in the light. Probably such is the case with the firefly.

28. *The Moore Light.*—In 1896 Prof. D. McFarland Moore brought out his vacuum tube light (Fig. 106). We visited an ordinary dry goods store which had been equipped with this. Glass tubing is put together very much as one would put up a stove pipe or a job of plumbing. The joints are

fused and made air-tight by playing a flame upon them after the pipe is up in place. This pipe is led around into all nooks and corners where there would be dark places. The air is pumped out of this tube and a trifling amount of some vapour is introduced, the kind varying according to the tint of colour which is desired.

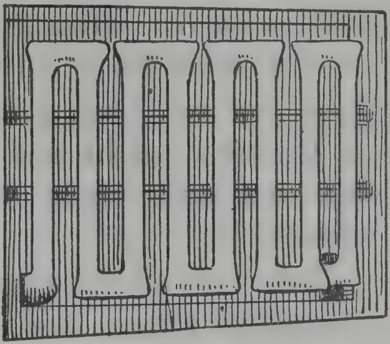


Fig. 106

Metal terminals are fused into the ends of this tube. The tube we saw was seventy-five feet long. A 1000-volt alternating current is applied to the terminals and the vapour becomes incandescent, filling the whole tube full of light. The first thing that the boys remarked was that although the room was brilliantly lighted no object cast a shadow. It seemed as though light was everywhere and there was no chance to screen it off.

29. *The Nernst Lamp.*—In 1897 the Nernst lamp appeared in Germany. It is a good illustration of an insulating substance becoming a conductor when heated to a high temperature. The "glower," as it is called, is composed of one or several short

rods of clay-like material. This is first heated by sending the electric current through resistance wire placed directly underneath it and connected in shunt with it. When it gets hot, current begins to pass through it, and is automatically cut off from the resistance coil. The glower produces an intensely bright and white light although it does not itself exceed the temperature of 1742 degrees.

Electric installations are now so carefully constructed that fires from poor insulation are very rare. Less than one fire in three hundred appears to be traceable to that cause.

30. *Electric Welding.*—Nothing is more common in electrical matters than heat produced by poor contacts. In this laboratory are two chandeliers, each controlled by a wall switch. After the current has been on the chandeliers for half an hour you will always find one of those wall switches warm, while the other is not perceptibly warmer than other objects in the room. The explanation is that there is poor contact in one of them. When two metal conductors touch one another at a mere point the electric current, in passing from one of these conductors to the other across such a narrow bridge, meets resistance and develops heat — sometimes

heat enough to fuse the point, and either break the contact, or, what is more likely, start a minute arc at that point. In some cases this makes the apparatus dangerously hot, and in other cases it bridges the gap with a broader and better contact — a true electric weld. Electric welding is applied to everything, from chicken fence to railway rails. Enormously large currents are used for the purpose, in some cases as high as 50,000 amperes being employed. The rails of railroads are welded end to end by a current of several thousand amperes sent through the joint by perhaps two or three volts. The joint heats and fuses together merely because the poor contact offers resistance to this enormous current.

IX

LIGHTING A SUMMER CAMP BY ELECTRICITY

SUMMER had arrived. The Science Club had held its last meeting for the season. Harold had engaged three other boys to spend the summer at the farm. I had the roof of an old mill reshingled and gave it to them for a camp. They were to make it over inside. I sent the boys to the country as early as it was possible for them to get away. It would be six weeks later before I could follow them.

When I did arrive I found they had elaborate schemes indeed. The first floor of the mill had been partitioned off into rooms, as shown in diagram (Fig. 107), *a*, *b*, *c* and *d* being bedrooms; *e* was a wash room, the like of which has never been seen before. It had not occurred to me that the mill pond *m*, which came to the very corner of the building, would furnish the boys a complete system of city water-works. At *g*, in the corner of this room, they had cut a hole in the floor and nailed slats

across upon the under side of the timbers, making a depressed floor for a shower bath. This was directly over a stream of water which issued

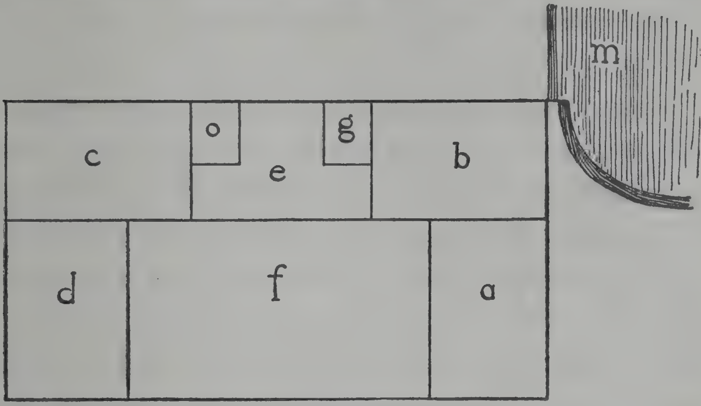


Fig. 107

from the mill pond. Hanging from the ceiling over this spot was the nozzle of a garden hose. The other end of this hose ran into the mill pond. The nozzle was capable of delivering either a stream or a shower, according to which way it was twisted in its socket. It was also capable of shutting off entirely the flow of water. The boys asked me to hold my hand in the shower, and to my astonishment it was warm. "What,

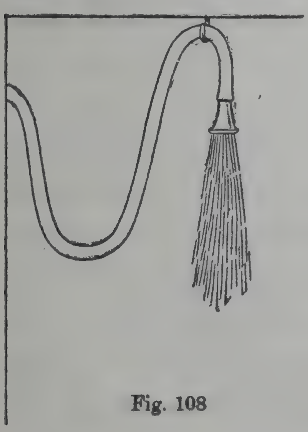


Fig. 108

pray, is your heating system?" I inquired. They invited me to go and see. Moored outside in the mill pond at the corner of the building was our motor boat, which the boys were allowed to use freely and which they understood as well as any one.

They said that ordinarily they used for the shower the cool water of the lake, which they much preferred, and which ran of its own accord, the lake being a trifle higher than the nozzle of the shower, but knowing my antipathy for the cold bath they had slipped the end of the rubber hose over the outlet pipe of the pump which served to cool the gasolene engine in the boat. The engine uncoupled from the propeller was heating and pumping water for my shower bath, and I immediately accepted the invitation to enjoy it.

Certainly no bath was ever more delightful than that one, coming, as it did, at the close of a hot, dirty ride from the city.

I had hastened the bath, because it was already dusk and I had no candle at the mill, but suddenly the room lighted up as if by magic. I saw then what had before escaped my notice, a miniature electric lamp, six-volt, two-candle-power, tungsten, such as are used for tail lights on automobiles. Since tungsten requires about 1.25 watts per candle-power

it was a 2.5-watts lamp, and since it was adapted to six volts it would take about four tenths of an ampere.

6 volts $\times$ .4 ampere=2.4 watts. The little wire filament looked to be about 1.5 inches long. Its resistance must have been 15 ohms.

6 volts $\div$ 15 ohms =.4 ampere.

A battery of five cells was used to furnish electric current for the lamp. Lamps were installed in the bedrooms also and were not intended to be used more than half an hour at a time. Dry battery cells are excellent for this purpose, and for so small a current the cheapest dry cells are as good as the more expensive ones. These cost fifteen cents a cell. They were connected by short pieces of bare copper wire; No. 18 "in series," as shown in Fig. 109. A wire ran from the central (carbon) binding post of one cell to the marginal (zinc) binding post of the next cell. This battery was placed on a shelf in a convenient place. A bare copper wire, No. 18, was attached to the carbon post at one end of the battery and another to the zinc post at the other end of the battery, and these two wires ran to all the rooms where lamps were placed. The wires were fastened up on the walls by staples, taking care that they should nowhere

come in contact with each other and "short circuit" the battery. Whenever it was necessary for one wire to cross another, small pieces of pasteboard were tacked up to prevent their touching each other. The lamps L (Fig. 109) were connected to these wires "in parallel." They cost forty cents apiece, and

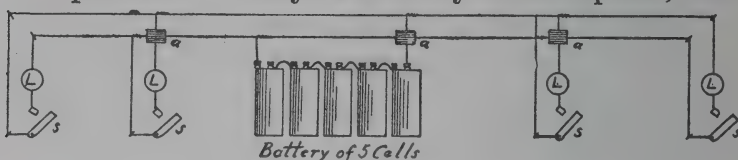


Fig. 109

the miniature sockets, into which they were screwed, cost five cents each. One of these sockets was screwed to the side of the door casing in each bedroom. Wires were attached to the line wires, simply by twisting them together. One of these came down to one side of the socket and the other came to the other side of the socket through a switch, *s*, made of a strip of sheet zinc. The cost of the entire installation was as follows:

5 dry cells at 15c	.75
5.2 cp., 6-volt tungsten lamps at 40 c	2.00
5 miniature wall sockets at 5c	.25
Wire, etc.	.20
	$3.20

Suppose each lamp is used thirty minutes a day for 100 days, making a total of fifty hours. There

are five lamps, making a total of 250 lamp hours. Each lamp takes .4 of an ampere, making a total of 100 ampere hours. The lamps are operated at six volts, making a total of 600 watt hours.

100	days
.5	an hour each day
50	hours
5	lamps
250	lamp hours
.4	ampere for each lamp
100	ampere hours
6	volts
600	watt hours

This amount of electrical energy would cost six cents if generated by a dynamo. It is generally stated that electricity costs fifty times as much if generated by battery as by dynamo. In this case the battery actually did serve for the whole season of 100 days and was not exhausted at the end of the season.

Indeed, since that season, the boys have found that battery cells which had been too much exhausted for use on the engine served very well on the lamps. By use the cells lose, not much in voltage, but in the ability to furnish sufficient quantity in amperes to make the hot spark required for igniting

the mixture of gasolene and air in an engine cylinder. When they have been discarded for use with the engine they may still furnish the small amount of current required for the lamps — provided not too many lamps are used at one time.

The dynamo current is always surprisingly cheap when compared with that produced by a battery, but, on the other hand, we are never as economical in the use of the dynamo current as we are with that of the battery.

If all five of the lamps in the above equipment were lighted at the same time and kept burning for half an hour, the battery would run down rather badly and would not fully recover. But if one only is used at a time and for not more than thirty minutes, or if more than one is used at a time and for a proportionately shorter period, the battery will receive no damage.

Dry battery cells may be purchased for either twenty-five cents or fifteen cents each. The chief difference is that the former are capable of giving larger current than the latter, when working against very small resistance. For example, the former may give twenty to twenty-five amperes on a short circuit, that is, connected directly with the ammeter without other resistance, while the latter may give

not more than six to ten amperes under similar conditions. For most purposes, other than igniting gasolene engines, in which dry cells are used, an exceedingly small current is required. The electric bell, for example, may not require more than .2 of an ampere and that intermittently. Now it is found by experience that the dry cells which are only capable of furnishing on short circuit six to ten amperes will last quite as long in bell work as one which may give on short circuit twenty to twenty-five amperes. Hence it is good economy to buy them.

"What a fine sitting room you have here! (Fig. 107, *f*.) When do you expect to fit it up?" said I. Instantly reminding myself, however, that boys do not want a sitting room, I inquired what they intended to use this fine, large room for. They told me that they had plans for making a machine shop out of that. The idea had been suggested by a counter shaft which still hung from the ceiling, and they had discovered that the old mill wheel would still roll over if the penstock were repaired. I replied that I would see what could be done about that sometime.

On the next day matters concerning the motor boat engaged our attention.

X

THE ELECTRICAL SPARKING EQUIPMENT FOR A GASOLENE ENGINE

UNDER the shade of a great sugar maple, with Millville Lake spread before us, we took apart and examined the entire equipment for producing the electric sparks to explode the mixture of gasolene and air in the cylinders of our motor boat. The engine has two cylinders. For each cylinder there is a separate battery and spark coil. Inasmuch as the electrical outfit is duplicated for each cylinder it will be necessary for us to consider the case of one cylinder only.

When this engine is running, 700 explosions per minute are produced in each cylinder. In one-twelfth of a second the following four events take place:

1. The cylinder is swept clear of the products of combustion formed by the last explosion.

2. Four drops of gasolene are vaporized and mixed with one quart of air and pushed into the cylinder by the pressure of the atmosphere.

3. This mixture is compressed by the piston in the cylinder to about one fifth its original volume.

4. The mixture is heated to its kindling temperature, which is above 2000 degrees. It then burns with a sudden expansion, which drives the piston before it and pushes the crank which is concealed in the lower end of the cylinder half-way around. The crank is attached to the shaft, which carries the fly-wheel upon one end and the propeller wheel upon the other end. The momentum of the moving parts — chiefly that of the fly-wheel — suffices to accomplish the remaining half of the revolution.

That any machine could be devised which could repeat these four events 700 times a minute was unthinkable a few years ago.

The first men who thought that a gasolene engine could be a practical thing were considered visionaries, but now they are found to be more practicable than steam engines. They are so efficient that they compete with the steam engine upon its own ground, and, in addition, they have opened up regions of usefulness which the steam engine can never exploit. So far as we can see, they have a permanent monopoly of the navigation of the air.

It is with the fourth event mentioned above, viz., kindling the explosive mixture, that we are

now concerned. The high temperature required for this is obtained by forcing an electrical current against resistance.

Five dry battery cells would very readily heat a short piece of fine wire to a sufficiently high temperature to explode the mixture, but it is impossible to alternately heat and cool a wire twelve times a second. It is too slow an operation. The only other method known at present is to imitate the lightning and force an electric current against the resistance of the air with sufficient power to produce the required heat. This, however, requires an extremely high voltage — at least 5000 volts, and our battery of five cells has not more than seven and a half volts of pressure. The interesting question then is, how does the spark coil enable us to raise the voltage from 7 to 5000.

To help toward an understanding of the matter I took seven small wire nails which I found in the boat — they were sixpenny finishing nails. I then took two or three yards of No. 24 insulated magnet wire, such as is used upon electric bells, etc. I use it more often than any other wire, and always have some about the boat. I fastened one end of this wire to one of the binding posts of a dry cell (Fig. 113), *a*, and attached branches *c* and *d*

to it. The other end, *b*, was left free to act as a switch for closing the circuit by touching it to the remaining binding post.

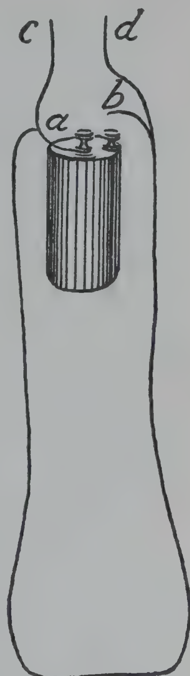


Fig. 113

One boy then touched the bare ends *c* and *d* to the tip of his tongue, while I touched repeatedly the binding post with *b*. There was, of course, no sensation. We now wound a portion of the wire upon the bundle of nails, laying on about fifty turns. (See Fig. 114.) The tongue was now placed at *T* and *b* was touched a few times to the free binding post. A very decided shock was felt, not while the end of the wire was resting upon *b*, but at the instant of touching and again at breaking the connection. The shock was noticeably stronger at the instant of breaking than of making the connection. There was also a spark formed when the connection was broken, which did not appear before the coil was made. We next wound on more of the wire — about fifty more turns (Fig. 115). When now connections were made and broken at *b* the tongue at *T* felt a much more decided shock, and a

larger spark occurred at *b* when the circuit was broken. Both the tongue and the spark indicate

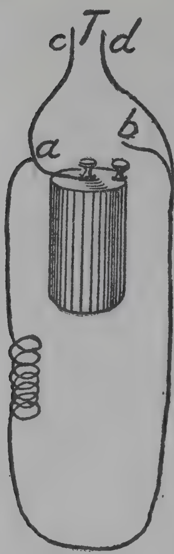


Fig. 114

that the voltage is creeping up very rapidly in this series of experiments. We next connected two cells in series, then three, four, and finally five cells in place of the one. The spark grew larger and "fatter," as the boatmen say, with each addition of a cell. It was not pleasant to use the tongue in the experiment after the number of cells exceeded two. I removed the branch *d* from the wire *b* and connected it to the binding post, as shown in Fig. 116. I then removed the crystal from my watch and poured into it a little gasolene. I rubbed the ends of *b* and *d* together over this, and when they separated the spark which was produced would not light the gasolene. We had made a coil which produced a spark that looked like a miniature flame, but still was not hot enough to set fire to gasolene vapour. It simply needs more iron in the core and more turns of wire about it. Bringing the ends of the wires together and

Fig. 115

Photograph by Helen W. Cooke

Feeling Electricity

separating them is somewhat like drawing an arc with the arc light carbons. It requires a vastly higher voltage to make a spark jump across an air gap than it does to lead it across thus.

The kind of coil we have made (only larger) is very much used in houses as a gas-lighting coil

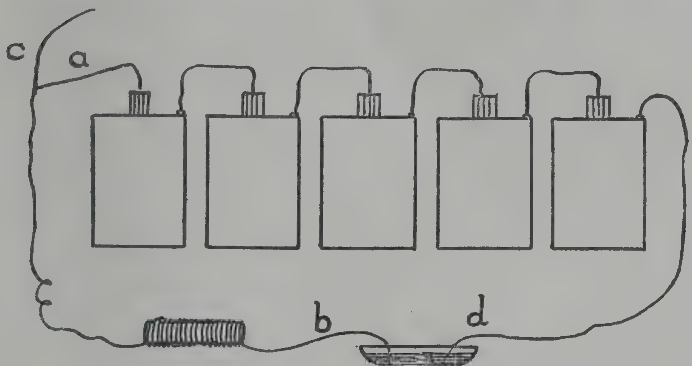


Fig. 116

(to be described later). It is very much used also for exploding gasolene engines. It generally passes under the name of the "make and break" coil. The revolving shaft of the engine is made to push together the ends of the wire and separate them at the right instant to make the spark for explosion. Of course this is done inside of the engine cylinder.

That type of coil does not offer resistance enough to protect the battery, and dry cells soon run down if used with it. The coils that we have in this boat

are somewhat different from that, the details of which we cannot now entirely explain.

They offer enough resistance to cut the current required of the battery down to one third what the "make and break" coil would take and at the same time they raise the voltage so much higher that the spark will jump across an air gap without being led across as an arc. Hence they are called "jump spark" coils.

It will be remembered that when we were studying the dynamo we produced an electric current by moving a magnet. We may now add that an electric current may be produced by simply changing the strength of a magnetic field. The coil that we have just made creates a magnetic field in the region about itself whenever a current is passing through it. The tongue at T (Fig. 117) detects an extra current while the magnetic field is being produced, or while it is dying away, or it will detect any slight variations in the strength of the current which produces the magnetic field. It is customary to distinguish between these two currents. The battery current which produced the magnetic field is called the primary current and the current which is detected by the tongue is called the secondary current. The primary current in our experiments

had only a few volts of pressure, from one to seven. The secondary current had many volts, as indicated by the spark. If we rub the end of the wire *c* across the binding post under *b* (Fig. 117) no spark occurs. The current does not in this case go through the coil, and no secondary current is produced. Whenever we touch the wire *b* to that post we have, in addition to the primary current which has not voltage enough to produce a spark, a secondary current flowing in the same wire at the same time and having voltage enough to produce a spark. The primary current is continuous while the contact is closed; the secondary current is momentary, as the tongue detects, and is produced only while changes are being made in the strength of the magnetic field. We will now take another piece of wire and wind upon the coil about two hundred more turns, leaving this outer coil wholly disconnected from the inner one, (Fig. 118). I connect *c* and *d*, the terminals of what we may call the secondary coil, with my measuring instrument and I connect *a*, one of the terminals of the primary coil, with the battery. I then rub *b*, the other primary terminal across the free binding post of

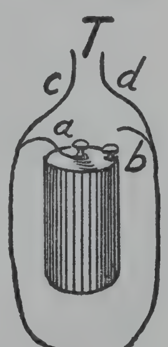


Fig. 117

the battery. At the instant of closing the primary circuit — that is, of building up the magnetic field — a secondary current is induced in the secondary coil, which lasts for only an instant, too brief a time for the needle to measure it, although its motion indicates both the presence and the direction of the induced current. While the primary circuit remains closed — that is, while no change is occurring in the strength of the magnetic field — the needle returns to zero, indicating no secondary current. But when now the primary circuit is broken and the magnetic field loses its strength, the needle indicates a momentary current in the secondary coil and *in the opposite direction from what it had been at first.*

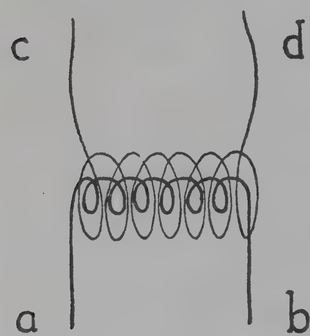


Fig. 118

If, therefore, I rapidly make and break the current at *b* I produce an alternating current in the secondary coil. I will connect *c* and *d* with a miniature lamp and, resting a coarse file upon the free binding post, I will rake the end of the wire *b* up and down upon this file so that, as it dances along upon the file, it will rapidly make and break the primary circuit, and therefore rapidly change the strength

of the magnetic field. You notice that the lamp lights up moderately well. It is being lighted by an alternating current. I move the wire a little more slowly and you see the flicker of the alternations. According to the label upon the lamp it requires ten volts, and our battery could not give that. We have therefore "stepped up" the voltage as we say and we have a veritable step-up transformer.

In this case the primary and secondary circuits are entirely separate. It is a familiar fact that different electric currents may pass through the same wire at the same time without apparent conflict. We send numerous telegraph despatches through the same wire at the same time. It is quite as easy for several pairs of persons to telephone over the same wire at the same time as it is for those same several pairs to carry on separate conversations in the same room at the same time, at, say, an "afternoon tea." We may use the same wire at the same time to carry direct and alternating currents. This fact was first discovered in 1902 by Bedell of Cornell University.

Primary and secondary currents do not require separate primary and secondary coils to convey them. They may or may not be connected into one continuous coil. It is quite immaterial whether

they are connected or not so long as they are in the same magnetic field. Indeed, it seems that the field outside of the wire may be quite as important as the wire itself.

We have now 100 turns in the primary and 200 turns in the secondary coils. Let us connect *b* with *c* so as to make one continuous circuit of 300 turns. Let us then put a branch upon *b* to connect with the battery, thus having 100 turns for the primary circuit, and put a branch upon *a* to connect with the lamp, thus having 300 turns upon the lamp, (Fig. 119). When now we rub *b* upon the file, as before, the lamp lights up more brightly than before, indicating that we have stepped up the voltage still higher. Varying the strength of the magnetic field induces a secondary current and the voltage of the induced current is determined, in part, by the number of turns in the secondary circuit. If what we have been saying is true we ought to be able to get these same results from an electric bell. To test this we connected wires with *a* and *c*, (Fig. 120), and since I knew that the secondary current at *S* would be too severe for the tongue

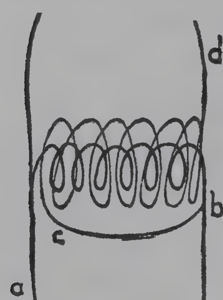


Fig. 119

we decided to feel it with the hands. For this purpose we want a larger surface than the wires themselves offer for contact with the hands, and so I twisted the bare end of each wire around an iron spike. The four boys then arranged themselves in line, joining hands, and the boy at each end of the line held a spike in his free hand. Thus we had put the enormous resistance of four human bodies joined

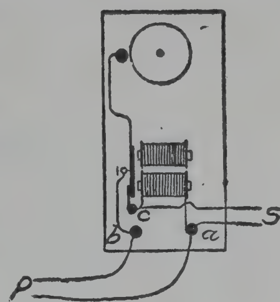


Fig. 120

in series in the secondary circuit. When now I connected two dry cells with *a* and *b* (*P*, Fig. 120) the hammer of the bell acted, like the file in the former case, as interrupter of the primary circuit. As it rapidly made and broke the primary circuit, it produced rapid changes in the strength of the magnetic field and thus induced a secondary current which the boys all felt. The fact that it forced its way through four bodies shows that its voltage was high. The high voltage was also indicated by the spark which always occurred in the bell. The primary circuit in this case has not more than three volts while the secondary has more than a hundred. We have it in our power to give the secondary current almost any voltage we choose, with this

limitation *each increase in voltage necessitates a proportional sacrifice of quantity.* The watt power induced in the secondary circuit cannot exceed that contributed to the primary circuit — indeed cannot quite equal it since there is some loss in heat.

Suppose we operate a bell on a primary current having three volts and .25 ampere, that is, .75 watt. Suppose then the voltage of the secondary current is stepped up to fifty times three, or 150 volts. The quantity of secondary current will be found to be somewhat less than one fiftieth of .25 or .005 ampere. The 150-volt alternating current from the bell is more tolerable than that from a 150-volt dynamo, because the quantity is limited in the former case.

Our spark coil has a vibrator which acts precisely like the hammer of the bell to make and break the primary circuit and thus make rapid changes in the magnetic field produced by the primary coil. The primary coil of the spark coil is many times larger than the coil of the bell, that is, it contains many more turns of wire. It has much more iron in the core. We use upon it five cells instead of the two cells upon the bell. The result of all this is that we have a much more powerful magnetic field than that in the bell and many more watts

of energy from which to induce a secondary current. Now the number of turns employed in the secondary circuit of our spark coil is very great, stepping its voltage up to thousands where the bell induced hundreds.

Suppose we now repeat our experiment in which we tried to light the gasolene in the watch crystal, using now the spark coil of the boat instead of our small "home-made" coil. In Fig. 121, B is the battery of five dry cells. *S* is a switch. *V* is the vibrator, which, like the hammer of an electric bell, makes and breaks the primary circuit. Of course the coil has a core of iron, although that is not here represented, and, of course, the coil has many hundred turns instead of the few here represented, and of course also it is built up of many layers instead of one as here represented. The secondary has very many more turns than the primary, but those in which the primary current passes are common to both circuits. There is also a condenser — not here represented, and not to be

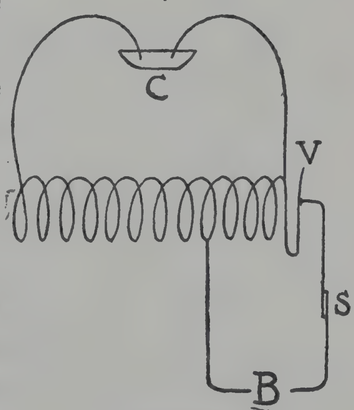


Fig. 121

described in this book. The result of all this is that the secondary circuit has a voltage of between 5000 and 10,000, and a spark jumps across the gap at c between one sixteenth and one eighth of an inch long. This spark is hot enough to light the gasolene which I have put in the watch crystal at c.

Let us return to the bell for a few minutes. I have here a miniature lamp which requires 10 volts and .1 ampere, that is, 1 watt, which I will connect at S (Fig. 122). When now I close the primary circuit with two cells at P you notice that the lamp lights up, but faintly. It is not receiving .1 ampere. Remember we have only .75 watt at our disposal and this lamp requires 1 watt. Hence it is getting only three quarters enough energy. We connect in a third cell and now it lights up to full brilliancy. The resistance of this lamp must be about 100 ohms.

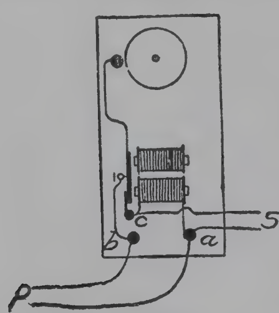


Fig. 122

$$\frac{10 \text{ volts}}{100 \text{ ohms}} = .1 \text{ ampere}$$

The resistance of the four boys might have been

60,000 ohms, and the voltage of the secondary circuit might in that case have been, say, 150.

$$\frac{150 \text{ volts}}{60{,}000 \text{ ohms}} = .0052 \text{ ampere}$$

How does it happen that the secondary current had a pressure of 150 volts on the boys but cannot supply even the 10 volts required by the lamp?

Perhaps we can be brought to appreciate the answer to that question best by asking ourselves some others quite like it.

Why did not the man who built our mill two generations ago locate it upon the small stream that flowed near his house? The small stream was more conveniently located for him and it has quite as much fall as he got at the foot of this lake. We sometimes express the fact by saying that the "head of water" or the water pressure was quite as much in one of these cases as the other.

One boy said that the stream sometimes gives out. Another one said that it never did have water enough to run that wheel. "Undoubtedly the trouble is with the quantity," said I, "but I want to show you that we cannot maintain the pressure unless there is sufficient quantity back of it."

In Fig. 123, suppose *A* represents a small, slim

tank of water three feet high. The water-wheel *W*, requires one gallon of water a minute pushed along by a three-foot head of water pressure to run it. The supply pipe *S* is bringing into the tank not more than one quart of water per minute. A gate at *R* enables us to regulate the flow of water, as we regulate the flow of electricity, by using more or less resistance. Now it is evident that if we close the gate, or partially close it, and allow the tank to fill with water, we may then open the gate and run the wheel for a short time, but the level of the water in the tank soon begins to fall and the pressure grows less and the wheel stops moving. It is just so with all generators of electric current. If we take from them more than they can supply continuously the voltage falls. This is notoriously true of dry cells. Like the water tank represented in Fig. 123, they "run down" if used continuously to furnish, say, one ampere of current, but they may furnish it for a short time, the voltage rapidly falling meanwhile. Then if given a short rest they "pick up" and will again furnish full pressure. The voltage of a

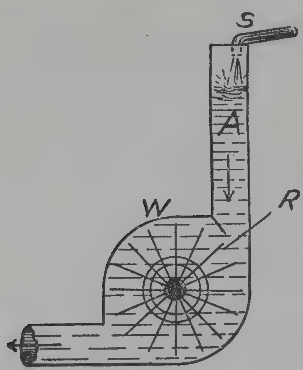


Fig. 123

dry cell falls somewhat when it is required to give the very small amount of current required to actuate a volt meter, say .015 ampere. Hence, our volt meter will not quite correctly show what the voltage of a single cell would be on open circuit. Notice that, when I put one cell upon this volt meter the needle shows 1.42 volts; but when I put four cells in series upon it the needle indicates six volts, as nearly as we can read it. That is, the voltage of each cell in this case appears to be 1.5. What has increased the voltage of a cell from 1.42 to 1.50? Simply this: when .015 ampere, the amount required by the volt meter, was taken from one cell it reduced its pressure, but when a multiplier with ten times the resistance was added we secured our reading by using only .006 ampere of current, and this did not appreciably reduce the true pressure of the cells.

The induced current from our bell when held back by 60,000 ohms of resistance in the four boys was able to push with 150 volts of pressure, and .0025 ampere passed without noticeably reducing this pressure, but when the same current was held back by only 100 ohms in the filament of the lamp nearly forty times as much current passed, and the pressure dropped to something less than ten volts.

"We will try an experiment to show how the volt-

age will suddenly fall when we reduce the resistance of your four bodies.

"Fill these two empty tin pails in which our lunch was brought with water from the lake and sprinkle in the salt left over from the lunch. Now twist a bare copper wire around the bail of each pail and connect these with the bell so as to get the induced current from its magnet. (See Fig. 124.)

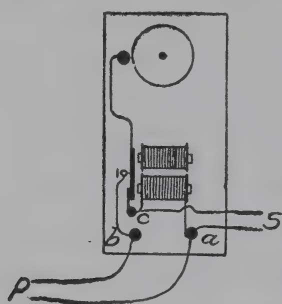


Fig. 124

Let the two pails of water be the terminals of the two wires at S. Now you four boys wet your hands in the water and then join hands, and those at the two ends of the line put your free hands upon the outside of the pails of water while I close the primary circuit. You of course feel the current just as you did when you held the spikes in your hands in a former experiment. But now you two end boys put your free hands into the salt water, and you instantly get a very smart shock. The resistance is no longer 60,000. It has dropped way down to 2000, and if the voltage had remained at 150 you would have received a terrible shock, but the voltage has dropped down to five. It is as though you had been pushing very hard against a post and it sud-

denly gave way. You cannot push against a thing which offers no resistance. So the voltage falls when resistance is reduced, and particularly if the source of supply has very little capacity. Here is another experiment you must try when you go back to the city. At a certain water faucet in my laboratory the pressure is disagreeably high. The water flows with great force and spatters badly. We can easily reduce the pressure so that the water will flow in a limpid stream. Fig. 125 shows the situation; *f* is the faucet, and in the pipe underneath the sink there is a stop-cock *c*. This may be adjusted permanently so that the faucet *f* will act pleasantly. The same thing is represented again at the gas stove. Let *f* in the Fig. 125 represent a gas cock at the stove. Suppose the pressure is so high that the gas flames pass more gas than is readily consumed. It is possible to adjust a stop-cock like *c* further back in the pipe so as to produce hotter flames, get rid of the poisonous fumes of half burned gas, and cut down the monthly gas bills one half.

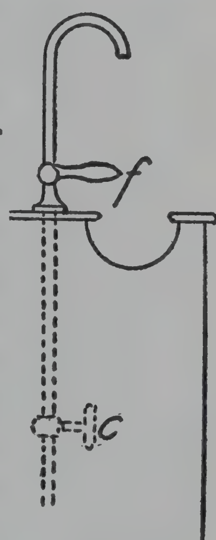


Fig. 125

"My garden hose will usually throw a stream across

the street, which is very desirable when one wishes to sprinkle the street, but this pressure is disastrous when I wish to sprinkle the flowers. Turning down the stop-cock at the nozzle makes it shoot a smaller stream but more spiteful in pressure, knocking the flowers to pieces and washing the soil away from their roots. But if I partially close the stop-cock at the side of the house where the hose is attached I may have the stream of water flow as gently as I choose.

"I should meet precisely the same situation if I tried to ring an ordinary electric bell by a 110-volt current, and I should use the same method of overcoming the difficulty.

"The great virtue of the dynamo is that it can furnish a large supply so that the voltage is kept constant on a great flow of current.

"Ernest asked awhile ago why he got a shock this morning in the motor boat when he touched only one binding post at the end of one of the spark plugs. That's rather a hard question to answer, but we have been working toward the solution and are now ready for and able to understand the explanation. We shall need another diagram to make it clear. In Fig. 126 *e* represents the binding post from which the shock was received. *B* is the

battery of five cells, *C* is the spark coil, *G* is the engine cylinder, *f* is the spark plug. When one wishes to start the engine he closes the switch *S*. This makes a continuous conductor from the battery to the metal cylinder itself. As the engine rolls over it closes the gap in the conductor at *d* for an instant. The primary circuit is then completed and the current passes from *B* to the cylinder, through the metal of the cylinder to *d*, then to the coil *C*, where it passes through a portion of the coil and then back to the battery. The vibrator on the coil causes the magnetic field to rapidly vary in strength. This induces a secondary current in the whole coil which, because it passes through a very great number of turns, has a high voltage. This passes from *C* through *B* to the base of the engine, then up the walls of the cylinder to the plug *f*, then jumps across the gap at *a*, causing the spark which explodes the mixture of gasolene and air in the cylinder. The spark plug *f* is porcelain — an exceedingly good insulator. Through the centre of this passes a wire from *a* to *e*. The current

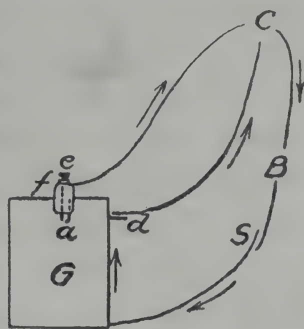


Fig. 126

passes up this and back to *C*. Now the engine rests upon the floor of the boat, and Ernest stood upon the same floor. The wood of this floor when dry and clean is a very good insulator, but when wet, and particularly when wet with water that has ever so slight an amount of any salt in solution, it becomes a conductor for such high tension currents. When therefore Ernest, standing upon the floor of the boat, touched the binding post, *e*, this induced current of high voltage found it about as easy to pass from the metal of the engine cylinder through the wood to his body and through his body to *e* as to jump across the short air gap at *a*. There are two things upon which he may congratulate himself.

"1. While the coil stepped up the voltage so high it reduced the available quantity of the current, so that the shock was a safe one.

"2. He received only a portion of the current which passed. The major part of it passed across the gap at *a*, otherwise we should have noticed that the engine missed an explosion when he touched the binding post."

The only part of this electrical outfit from which one may receive a shock is that line from *e* to *C*. The greatest difference in electric pressure is always to be found between the two extremities of the

electric generator; as, for example, between the carbon end and the zinc end of the battery, the positive and negative poles of the dynamos; the right-hand and left-hand end of this coil. Since the right-hand end is connected by good conductors with the metal of the engine and with the floor of the boat and through it with our bodies, we are in the same electrical condition as the right end of the coil; but the left-hand end and the wire connecting it with *e* are forced by the varying magnetic field into a very different state of electric tension, and it is insulated from the engine and from us by the porcelain spark plug. We say that the "difference in potential" between the two sides of this system is 5000 to 10,000 volts.

The water in this lake flows through the stream at the other end of the lake to the ocean. The water of the ocean evaporates to form clouds. Clouds drift over the land and drop their rain to replenish the lake. The difference in water level between this lake and the ocean is twenty feet. A difference in water level is what makes it a water power and it is what occasioned the building of our mill. This difference of water level corresponds in our electric generators to the difference in potential. The difference in potential main-

tained by our battery of five cells when not producing current is 7.5 volts. The difference in potential between the two ends of our coil, when the battery is agitating its magnetic field, is perhaps a thousand times as much, or 7500 volts.

The boys took their swim in the lake and afterward, while we were all on shore lying on the grass, they brought up again the question of the machine-shop. They were anxious to know if I had any plans in regard to it. I said I had been thinking about it a good deal over night but had been waiting to hear their plans. Well, they thought it would be good to have a turning lathe, but could not think of anything else unless it might be a grindstone run by power. I said I had thought of a Central Station Electric Plant. At this they all sat up.

"Hydro-electric stations are the proper thing now," I remarked. "On the Rio Grande River in Colorado they are constructing several plants where water power will be utilized to generate electricity for use more than one hundred and fifty miles away. For transmitting electricity to such a distance they step up the voltage, or electro-motive force as it is called, to 100,000 volts.

They are harnessing the Au Sable River in Michigan to generate electricity and transmit it at 135,000

volts e. m. f. to towns nearly two hundred miles away. Electricians use e. m. f. for electro-motive force, just as you boys use "exams." as slang for the motive force in school.

Of course we are aware that since 1896 some of the water power of Niagara had been converted into electric power to run street cars and factories and furnish electric light and electric heat as far away as Buffalo, twenty-six miles distant.

About $18,000,000 are now being invested in hydro-electric enterprises even in Mexico.

By this time the boys were all standing up and staring at me, while Harold inquired if I were talking in my sleep. "I have at any rate succeeded in waking you all up," said I, "and what I have said is not altogether a joke. Let me explain somewhat at length."

XI

ELECTRICITY FROM CENTRAL STATIONS

LARGE dynamos generate electricity very much more cheaply than small machines can, and machines which have a full load continually produce the current very much more cheaply than those which run upon very light load part of the time. The largest central stations with load evenly distributed for the whole day could furnish electricity profitably at four cents per kilowatt hour. There are many small electric lighting plants which furnish current from sundown to midnight only at fifteen cents per kilowatt hour, with little profit. The transformer (Fig. 127) makes it possible to gather all this generation of electricity for sparsely settled districts into large central stations, located sometimes far away from the consumer perhaps, where there is abundant power in some water-fall, thus saving the expense of coal for running the dynamos.

A few years ago there were no central stations

for this purpose. Now according to the latest census reports there are in the United States about 30,000 plants, including those which belong to certain cities, that generate electricity for sale, and there are twice as many more isolated plants to furnish light and power in factories, hotels, etc.

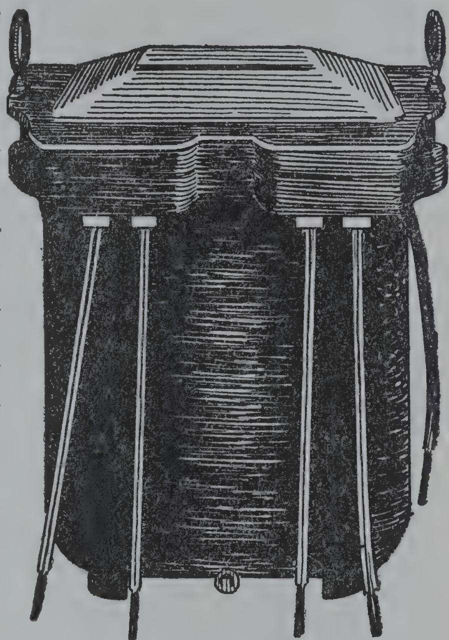


Fig. 127

The money invested in central station business now exceeds six billion dollars, and the annual output of electric current is sufficient to keep eight billion 16-candle-power carbon filament electric lights burning continuously night and day. All this has more than doubled in the last five years. Central stations are now furnishing about five times as much current for heating, cooking, and charging automobiles as they did five years ago. About one third of all the central stations depend on water power.

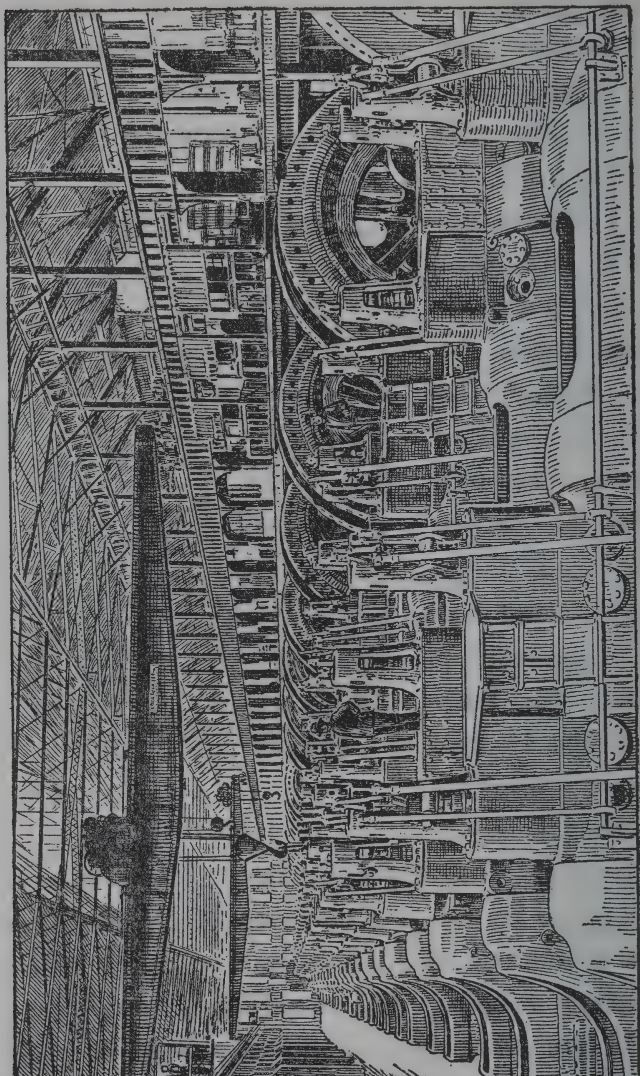


Fig. 128

We might take as the type of hydro-electric central station, that is, one which generates electricity by water-power, the Glenwood Station of the Central Colorado Power Company. This station has two 9000 horse-power water turbines. Each water-wheel drives an alternating-current generator which develops 4000 volts of e. m. f. These water wheels and generators are shown in Fig. 129. The penstocks are to be seen coming through the back wall of the building. They bring water at 170 foot head, or about seventy-five pounds per square inch static (standing) pressure. Three huge transformers, each weighing twenty-six tons, step up the e. m. f. from 4000 to 100,000 volts. These are the cylinders shown in Fig. 130. They simply contain a great many coils of copper wire with a vast amount of iron at the centre. They accomplish in a large way what our spark coil does in a lesser degree. But why go to all this expense to produce such a dangerous and troublesome voltage? The answer briefly is, that while it is dangerous and troublesome the expense is not so great as it would be to supply by any other method the electric current required. Denver and numerous other places, large and small, require electric current. From one to two hundred miles away

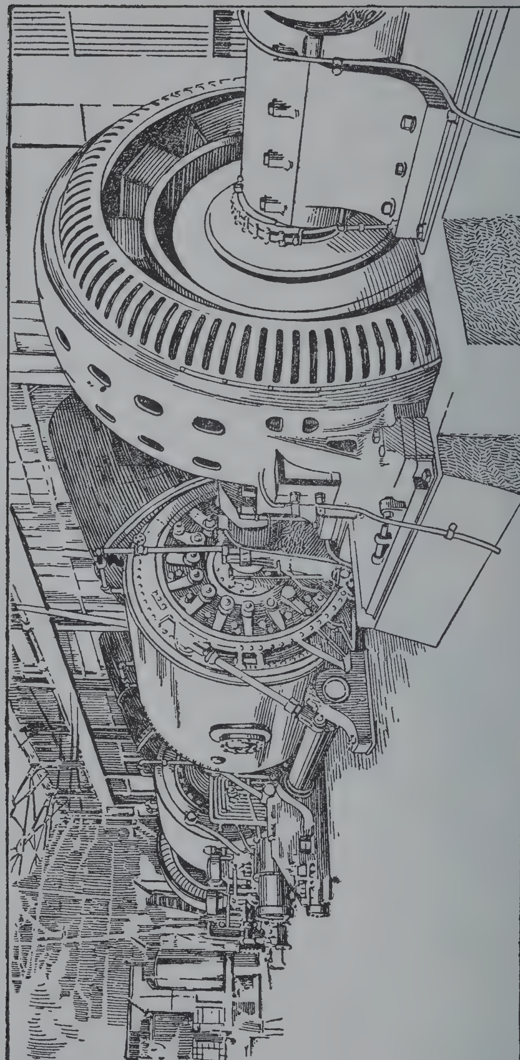


Fig. 129

on the Grande River, there is vast power running to waste. We have to choose on the one hand between buying power in the shape of coal and

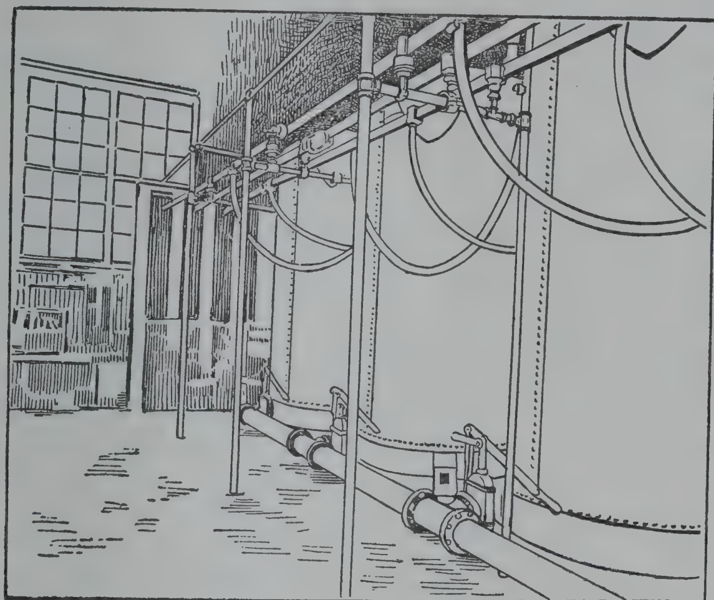


Fig. 130

distributing power plants to those various localities where electricity is needed, and on the other using this water-power, which is now running to waste, to generate electricity which we may transmit and distribute throughout the one hundred and eighty-five miles to Denver, Leadville, Boulder, Dillon, Idaho Springs, etc. But electric energy transmitted a long distance suffers great loss.

Suppose, for instance, I needed to supply fifty amperes at one hundred-volt pressure ten miles distant from the generator, and had a conductor the size of a trolley wire to bring the current. The resistance of the trolley wire is one ohm for every two miles, or five ohms. The drop in voltage is found by multiplying the amperes of current by the ohms of resistance. Ten miles from the central station, therefore, the drop on fifty amperes would be $50 \times 5 = 250$ volts. It would, therefore, be necessary to maintain a pressure of 350 volts at the generator to deliver the fifty amperes at 100 volts. The energy supplied by the generator is 350 volts $\times$ 50 amperes $=$ 17,500 watts $=$ 17.5 K. W. The energy delivered to the consumer is 100 volts $\times$ 50 amperes $=$ 5000 watts $=$ 5 K. W. In order to deliver fifty cents' worth of electricity per hour to the consumer it would, in this case, be necessary to generate $1.75 worth of electricity at the central station. That is, about seventy per cent. of the energy generated would be wasted in transmission. If now we decide to generate this electrical energy at ten times as high voltage it will be necessary to transmit only one tenth as many amperes, or five. In this case the drop in voltage would be 5 amperes $\times$ 5 ohms $=$ 25 volts. It would be necessary to

maintain 1025 volts of pressure at the generator to deliver to the consumer the five amperes at 1000 volts = 5000 watts. That is, to deliver 5000 watts in this case we must generate 1025 volts × 5 amperes = 5125 watts, and less than 2½ per cent. of the energy generated would be lost in transmission.

If now the consumer must have his energy delivered at 100 volts, we must introduce a step-down transformer at his end of the line which may give him 50 amperes at 100 volts = 5000 watts. This transformer, being small, will cause a loss of 15 or 20 per cent., but if there were a very large amount to transform it might be done with a loss of only 4 per cent.

It is not thought to be advisable to raise the voltage at the generator higher than 4000. This will not suffice to supply large working currents to a greater distance than about six or eight miles. For a distance of 10 miles 6000 volts are desirable; for 50 miles 30,000 volts; for 100 miles 60,000 volts; for 165 miles 100,000 volts; and for 200 miles 120,000 volts. Notice that in this table the voltage rises at the rate of 600 per mile. Since it is not desirable for the generator itself to produce a higher voltage than 4000, we must depend upon transformers to

produce these high voltages. Let us then consider, a little more in detail, the construction of a transformer. I have here some drawings of one which I propose that we make in the machine shop, and use in our central station equipment in the future. We will procure the thinnest and softest sheet iron possible and cut out of it a lot of pieces shaped like the letter H with the dimensions shown in Fig. 131. These are to be piled one upon another, with strips of paper between, until the pile is $1\frac{1}{2}$ inches thick. Then four pieces of board are to be bolted to the sides of these (Fig. 132). The dimensions of each of the four blocks, is to be $7\frac{1}{2}$ inches long by 3 inches wide by $1\frac{1}{2}$ inches thick. Upon the cross bar of the H we will wind 400 turns of No. 12 double cotton-covered copper wire, bringing out the ends for future attachments, and then wind on 1200 turns of No. 10 double cotton-covered copper wire. The

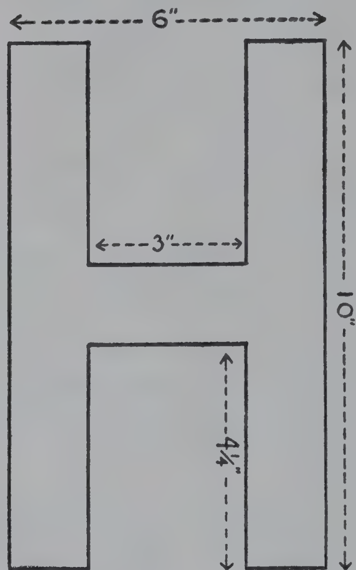


Fig. 131

wire will fill the space between the blocks as indicated by the diagram in Fig. 133. We will then cut strips of the sheet iron 6 inches long by 1¼ inches wide, and bridge across the ends of the H, prying open the leaves of sheet iron and tucking them in between as shown in Fig. 134. We shall then drill a hole at each corner and bolt them in place. Binding posts will be placed at *a*, *b*, *c*, and *d* (Fig. 134), and the two ends of the No. 12 wire will be brought to *a* and *b* and those of the No. 18 wire will be brought to *c* and *d*. Going through all this detail of construction has probably made you lose sight of the essential features of this transformer. Let us for a moment turn back and see what they are. We have a large coil of wire 3 inches long and 7½ inches in diameter. It is composed of a coarse winding and a fine winding, which we may designate as the primary and secondary coils, if we choose. Of course the only reason for having different sizes of wire is so that we may send larger currents through one than the other. The coil has a laminated iron

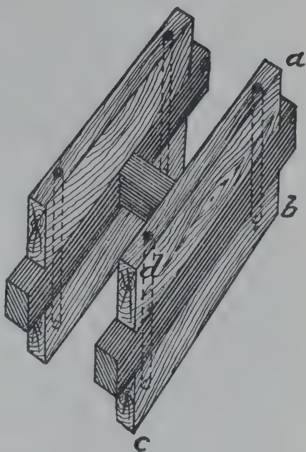


Fig. 132

core, that is, it is composed of layers of sheet iron. These layers are insulated from one another. This is essential, although we cannot explain why now. But perhaps the most essential feature of the transformer is that iron extends clear around from one pole of this electro-magnet to the other. Fig. 135 represents a section through the coil made in the plane of *e f g* (Fig. 134). The core of the magnet is represented as heavily shaded. The *magnetic circuit* is said to be closed from one pole of this magnet to the other through the strips of iron which pass across the ends and down the sides of the coil. The arrows show the path of the magnetic circuit. The dotted portion shows where the copper wire may be supposed to have been cut

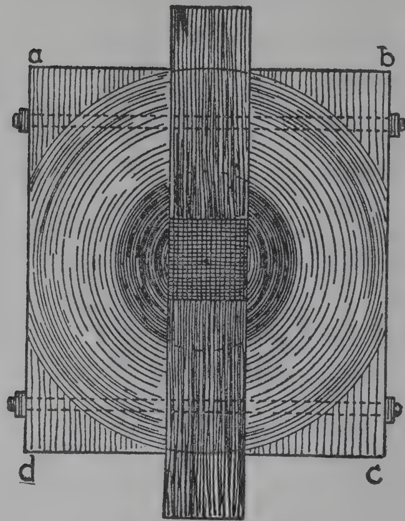


Fig. 133

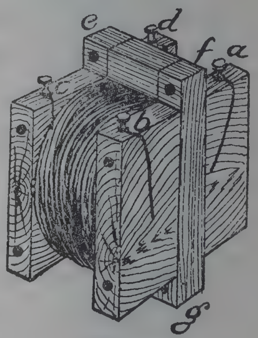


Fig. 134

Photograph by Helen W. Cooke

Operating the Switchboard

across. Inasmuch as the electric current is induced in the secondary circuit by continually varying the strength of the magnetic field as much as possible, the alternating current is the most desirable to use in the primary. If the direct current were used an interrupter would be necessary, which would of course produce too much sparking when any but low tension currents are used in the primary circuit. The most interesting and curious fact about the transformer is that the voltages of the primary and secondary currents are in exact proportion to the number of turns in the wire of the two circuits.

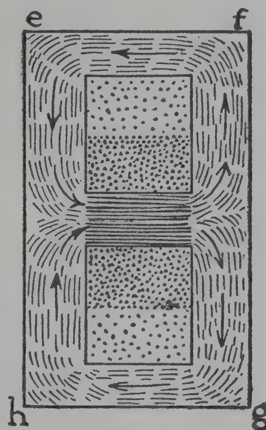


Fig. 135

In our transformer the number of turns in the coil between the binding posts *a* and *b* is 400 and the number of turns between *c* and *d* is 1200. If now we connect a 112-volt alternating current with the binding posts *a* and *b*, a volt meter connected across between *c* and *d* will show 336 volts, and if *b* and *c* be connected by a short wire, bringing in 1600 turns into the secondary circuit, a volt meter connected across between *a* and *d* will show a voltage of 448.

Or if, leaving *b* and *c* still connected by a short wire, we connect the 112-volt alternating current to *a* and *d* a volt meter connected across between *a* and *b* will show 28 volts, or if connected between *c* and *d* it will show 84 volts, and if finally the 112-volt current is connected to *c* and *d* the pressure between *a* and *b* will be 37⅓.

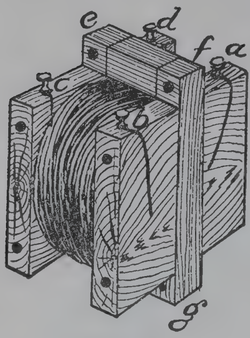


Fig. 136

The story, then, of the central station which we have chosen as a type is briefly this: Falling water makes dynamos revolve, generating a 4000-volt alternating current. This current is sent through the primary windings of transformers. The secondary windings of these transformers have twenty-five times as many turns as the primary coils. This steps up the voltage from 4000 to 100,000, making it necessary to send only one twenty-fifth as many amperes over the lines as would be required at 4000 volts, and reduces the loss in transmission to nearly one twenty-fifth. At the other end of the line the current traverses the secondary windings of transformers, and the consumer receives his current from primary coils which may step the e. m. f. down to any required volts of pressure, generally 110.

Now I shall be glad to have you consider whether this suggests any practicable problems for us here in Millville.

The sun is nearly setting and I suppose the family is expecting me home.

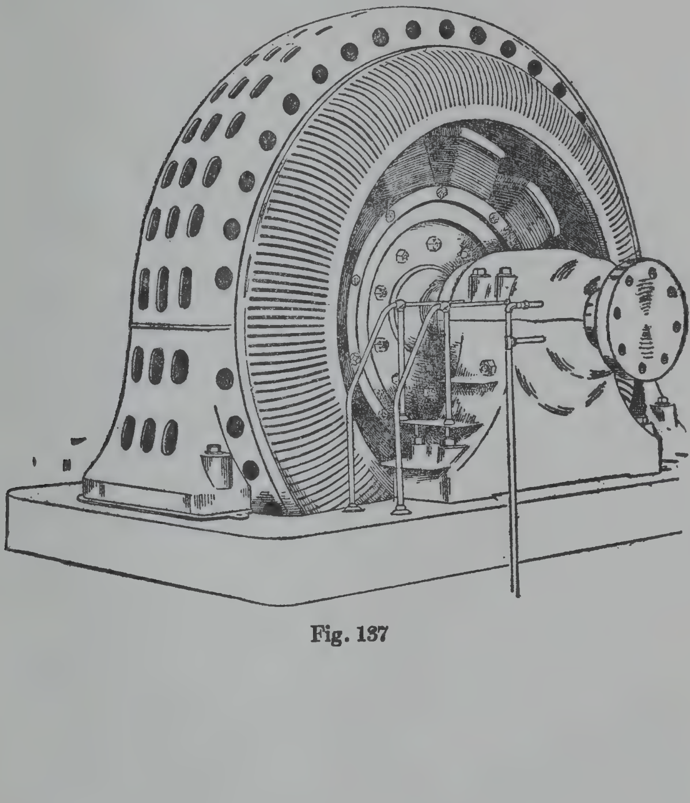


Fig. 137

XII

ELECTRICITY FROM AN OLD MILL

MILLVILLE is only a name or rather a reminiscence. There was once a village here, but now its population has all gone with the tide down the river, even its ghost appears to have departed. The ruins have all fallen, except the mill, which we propose to revivify.

I had built a summer cottage on the shore of the lake, about one mile from the mill. The absolute stillness of the place charmed me when worn out by the noise and heat and dirt and smell of the city. Here even the owl twittered softly as if afraid to disturb the silence.

The silence which was such a boon to me seemed to be oppressive to the younger members of the family. To prevent therefore their becoming dissatisfied with the place and wishing to go to other resorts, I planned to have some of their best friends spend much of the summer with us, and I encouraged their plans for making use of the mill. I will not

offer this as an excuse for introducing electricity into a sleeping valley. Indeed, electricity has always disported itself there in the lightning, jumping from cloud to mountain peak as I have seen it nowhere else on earth.

The next time I saw the boys they had ambitious plans indeed. The penstock at the mill was to be repaired. The water-wheel was to drive an alternating current dynamo. The voltage of this current was to be stepped up by a transformer. It was to be transmitted to the cottage and there the e. m. f. was to be stepped down again by another transformer. My wife suggested that if it interfered with the simple life it would have to step down and out. Harold, however, assured his mother that they were going to simplify everything — even the subject of electricity.

Their plans were: To light the cottage by electricity; introduce a number of electric back logs, with coloured glass bottles; heat the fireless cooker by electricity; pump the water for the house by electricity; run mother's sewing machine by electricity; run the washing machine and wringer by electricity; heat sad irons by electricity; percolate coffee, wash dishes and run the vacuum cleaner by electricity; operate the door bell and the telephone

and wind the clock by electricity. I was sure that if they carried out these plans they would stay in Millville at least that summer, so I said go ahead.

We fixed the penstock. The boys estimated that 10 cubic feet of water per second would pass through it. They said that a cubic foot of water weighed 62.5 pounds and 10 cubic feet weighed 625 pounds. They said it fell at the rate of 7 vertical feet a second, making 4375 foot-pounds per second. But 550 foot-pounds per second is one horse-power, hence this is about 8 horse-power. Since one horse-power is equivalent to 746 watts of electricity, we have, if we could generate it without loss, said the boys, nearly the equivalent of 6 kilowatts of electricity, or about 54 amperes at 110 volts.

There were several things they wanted to know before they could go further with their plans.

1. How many of these electrical appliances we would be likely to use at one time.

2. How much current each device would require.

3. How much they must allow for losses in generating the current, in transmitting it, and in transforming it.

We assured them that we would never use more than twenty amperes, say, two thousand watts at one time. They might install a fuse, or circuit

breaker in our line to protect their plant against a greater load from us. I told them that they might allow 20 per cent. loss of energy at the dynamo in converting water-power into electric-power.

I would suggest generating their current at 115 e. m. f. and stepping it up to 460 for transmission to us, and then stepping it down to about one hundred and ten volts for our use. They might count on about one-third loss on our supply, that is, they would need to generate about three thousand watts in order to deliver us 2000 watts.

I suggested making our line of No. 6 copper wire, which has a resistance of two ohms to the mile. The distance from the mill to the cottage is one mile, and the complete circuit therefore would require two miles of wire, or four ohms of resistance.

If we start with 3000 watts and lose 14 per cent. in transforming we shall have 2580 watts to transmit. If the voltage has been stepped up fourfold there will be about 5.6 amperes to transmit which will suffer a loss of 22.4 volts in passing through four ohms of resistance on the line. The loss in transmission will be about 5 per cent., and we shall have on arrival at the cottage about two thousand four hundred and fifty watts with a voltage of 437.6. If now in stepping this down to one fourth the

voltage, viz., 109.4, we lose 14 per cent, we shall have left something over two thousand one hundred watts, or nearly twenty amperes.

Assuming that you are able to generate 4800 watts of electricity and that 3000 watts must be furnished for transmission to the cottage, you have left 1800 watts, which will give you something over fifteen amperes at 115 volts for use in your machine shop. I suggest that we get a dynamo which will generate both alternating and direct current—the alternating current you will send to the cottage, and the direct current you will have for use at the machine shop.

But how is it possible for a dynamo to generate both alternating and direct current at the same time?

Recall that all dynamos are generators of alternating current. If the brushes rest upon rings upon the axle they send forth alternating current — but if the brushes rest upon commutator bars they send forth direct current. Now we will have two sets of brushes, one pair of which shall rest upon the rings on the axle, and they will collect alternating current for the cottage, while the other pair will slide over the commutator bars and collect direct current for the machine shop. I have constructed a model which will make it plain. Here is

a piece of a broom handle (Fig. 138), one foot long, which shall represent the axle of an armature. *a b c d* is a stout wire which represents the coil of the armature. In this case it has no iron at its centre. Nevertheless it will serve as an armature having one loop of its coil left. *e* and *f* are rings, sawed

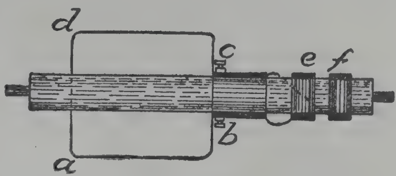


Fig. 138

from a piece of brass pipe, which fit snugly upon the axle. Another ring of the brass pipe was sawed lengthwise, as shown in Fig. 139. These two halves are also fastened upon the axle and one end of the wire loop, *c*, is fastened to one of these,


Fig. 139

and the other end of the loop, *b*, is fastened to the other half of the ring. These two halves of the piece of brass pipe are placed so that their edges are near to each other but do not touch on either side of the axle. The two ends of this wire loop are also connected with the rings *e* and *f*. A short wire connects *b* and *e* and another connects *c* and *f* passing through the wood of the axle, as shown by the dotted line. We will now revolve this loop slowly about its axle in a strong magnetic field. To produce this field I will send two amperes of electricity through the coils of wire (Fig. 140), which

surround two iron pole pieces that are screwed into an iron base. Between the poles *N* and *S* of this electro-magnet we will thrust this wire loop and revolve it as an armature very slowly. Meanwhile I connect two wires to my sensitive ammeter and let their free ends brush along on the rings *e* and *f*. The needle of the ammeter swings to and fro for each half revolution of the armature, showing an alternating current of .01 amperes. If this armature had many turns of wire instead of this one loop, if it had an iron core, and if it should revolve at high speed, the results would differ in degree but not in kind.

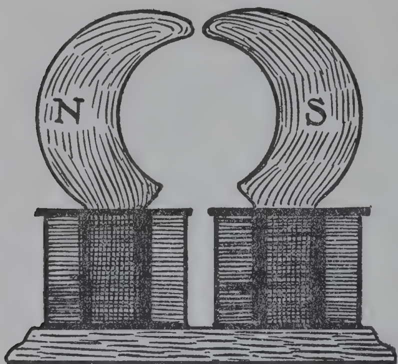


Fig. 140

We will now move the wires which are acting as brushes over to the metal pieces *b* and *c*. When now we revolve the armature the needle swings to the right, and just as the needle is about to swing back each brush slides from the plate on which it is rubbing to the opposite one and the needle gets another impulse forward. If the armature is turned rapidly the pulses disappear and the needle stands

constantly at about .015 amperes. This then is both an alternating and a direct current dynamo. It simply needs more iron, more copper wire, and more rapid motion, to give us the 4800 watts of electrical energy we are seeking.

"But how shall we produce the current which we wish to send around the spools of the field?" inquired the boys.

"Connect the field with the brushes which rub upon the commutator," I replied. "It will magnetize its own field."

As good luck would have it, we found that the ledge of rock which furnished the basis for the mill dam was immediately underneath the floor at the north end of the machine shop. Upon this we built up a solid foundation for the dynamo. Our water-wheel gave a speed of 240 revolutions per minute to the counter shaft. A pulley of two feet in diameter upon this countershaft was belted to the pulley of one foot in diameter upon the dynamo — thus giving its armature a speed of 480 revolutions per minute. We had to fix a governor upon the water-wheel to keep this speed constant at varying loads. The voltage is very sensitive to slight changes in the speed of the generator.

We had next to plan what equipment we should need for the machine shop and to decide where to locate each machine. The first machine we installed was a lathe adapted for use both with metals and wood. Among the adjuncts of this were all sorts of drills, chisels, circular saws, grinding and burnishing tools, etc. The second machine located was a small forge with an electric fan to furnish the blast. These were followed by a small band saw and a small planer. The fifth machine was a big grindstone and the sixth was an emery wheel. The boys had a long discussion, running through several days, on the question whether these machines should be belted to the counter shaft, and thus get power directly from the water-wheel, or whether each machine should be operated by an electric motor attached to it.

Harold said: "Suppose I want to saw a piece of wood requiring a horse-power, I must start an eight horse-power water-wheel which will run a six-horse-power dynamo which will operate a two-horse-power motor that will revolve the saw. There is a loss in each machine, and the lighter the load the greater the loss. In order that the motor may deliver one horse-power to the saw, it must receive from the dynamo, say, one and one-half horse-power, and in

order that the dynamo may deliver to the motor one and one-half horse-power, it must receive from the water-wheel, say, two horse-power. What is the matter with my saving time and energy by sawing off the block with my own right arm?"

"But," said Ernest, "you forget that this water-wheel and the dynamo must run all the time by the terms of our agreement with the cottage, and they will run fairly well loaded, so that the starting of the saw will not entail any such losses as you reckon. Furthermore the water-power is running to waste, anyway. You simply divert its channel when you start all this machinery. That's all. And lastly, if the saw requires a horse-power, as you say, your right arm could not furnish it."

"Oh," interposed Dyne, " it would take a horse-power to do it as quickly as the machine does, but Harold simply proposes to take more time in sawing the block and less in running the machinery. An infant can do the work of a horse if you give him proportionally more time."

"I don't like the idea," drawled Erg, "that this machinery has got to be kept running all the time. When will a fellow get a chance to sleep or go a-fishing or have any vacation, with this central-station machine shop on his hands all the time?"

I had inquired how the last two boys won their nicknames of *Dyne* and *Erg* and had been informed that one was very keen about dining and the other had a great aversion for work. They had doubtless seen these terms somewhere in their reading of physics, but they appeared to have forgotten their significance by a too familiar use of them. I told them that these were sacred terms, the first being a name for the unit of force, while the second designated the unit of work. Both boys said that under those circumstances they would like to shed the names. The names, however, stuck and the boys themselves might, I think, be said to exercise a maximum of power with the least waste of energy.

This idea of running the plant continuously had evidently received no attention hitherto and it bid fair to quench all the enthusiasm until I came to the rescue by proposing a storage battery.

If we can procure a battery in which we may store energy, which shall always be on draught by merely pushing a button, one which "is not injured by overcharging nor too rapid discharging, nor even by complete discharge"; one which is not injured by standing idle for any length of time, either charged or discharged; and finally one which "is practically foolproof"— we want to try it. I propose that

you appoint a committee to look into it. But at any rate this enterprise must go on even if I have to hire a man to live in the loft of the mill and keep the machinery going.

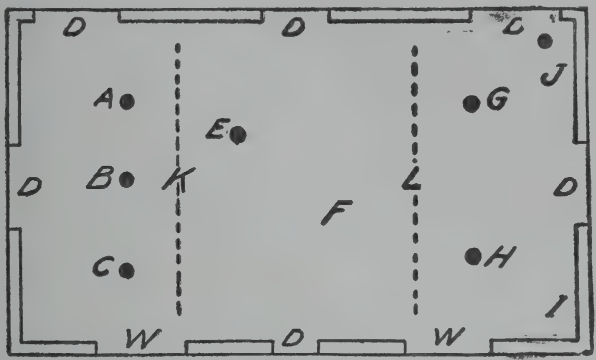


Fig. 141

"No man in the loft," said Dyne, "while I have my rations."

"There will be no need for him so long as I can store energy here," said Erg, "so let the job of equipping the establishment go on in the regular fashion."

After a long confab one evening at the mill we settled upon the arrangement shown in Fig. 141. *D* represents the location of the doors and *W* that of the windows. The equipment is designated as follows: *A*, saw; *B*, planer; *C*, lathe; *E*, emery wheel; *F*, grindstone; *G*, dynamo; *H*, forge; *I*, storage battery; *J*, switchboard; *K* and *L*, counter

shafts suspended from the ceiling. The water-wheel is belted directly to the counter shaft *L*. This revolves at the rate of 240 r. p. m. A two-foot pulley on this shaft is belted to a one-foot pulley on the dynamo *G*, giving the dynamo a speed of 480. A 4-inch pulley on this counter shaft is belted to a16-inch pulley on the grindstone *F*, giving the stone a speed of 60 r. p. m., or one revolution per second. A 32-inch pulley on shaft *L* is belted to an 8-inch pulley on the countershaft *K*, giving a speed of 4 times 240, or 960 r. p. m. 12-inch pulleys on this shaft are belted to 6-inch pulleys on each of the machines *A*, *B*, and *C*, giving them a speed of 1920 r. p. m., and a 16-inch pulley on this shaft is belted to a 4-inch pulley on the emery wheel, giving it a speed of 3840 r. p. m. As soon as everything was in running order, Harold took his mother down to the machine shop and started all the machinery going at once, and while they stood in the middle of the room I heard him explaining to her how she might find out the speed of each machine. He said that she must start with the grindstone, because that goes slowly enough to count. She held her watch in hand and counted the number of revolutions in a minute, as he directed, and found them to be sixty. Then he asked her to judge how much larger

the pulley on the grindstone was than the corresponding one on the counter shaft. She said that she thought it looked four times as large. He told her that she had it just right, and explained that the shaft must move four times as fast as the stone, or 240. "Now how fast do you think the emery wheel is going?" She acknowledged that she had no idea.

"Well," said he, "when you get real used to it you can tell by the tone a wheel makes just about how fast it is going."

Then he explained how she might calculate its speed by looking at the pulleys, and she found that the counter shaft was going four times as fast as the shaft *L* and that the emery wheel was going four times as fast as *K*. Hence it was going sixteen times as fast as *L*, or 3840 r. p. m. His mother said she thought that it was fascinating to stand in the middle of the room with the slowly moving grindstone on one hand and emery wheel moving sixty-four times as fast on the other hand and think that they were propelled by the same water-wheel. I handed Harold a speed indicator which I had just received, (Fig. 142), the mechanism of which was all visible. Harold looked at it for a minute and found stated upon it that the wheel *B* had 100 cogs,

and he very quickly inferred that the axle A, whose screw threads fitted into these cogs, must revolve one hundred times each time the wheel B revolves once. The tip end of this axle had a soft rubber cap C. Without suggestion from me he soon held this rubber shoe against the end of the axle of the emery wheel and counted, not thirty-eight, but thirty-six revolutions of the wheel of the speed indicator in one minute. This puzzled him and he inquired how it happened that the emery wheel made only 3600 rather than 3840 revolutions per minute.

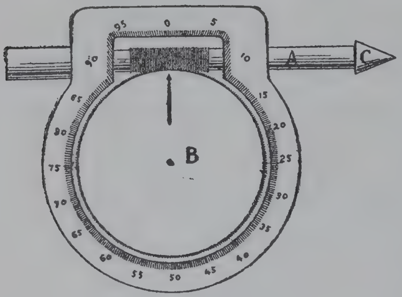


Fig. 142

"Well," said I, "we always have to count on belts slipping some, particularly upon very fast moving pulleys and upon very small pulleys. Here are two belts to slip, and still you are losing only the effect of one revolution of the countershaft L in a minute. Grind something on the emery wheel and you will find that the belts will slip more. In fact, grinding upon the emery wheel will compel the water-wheel to go more slowly until its governor opens and gives it more water. The water-wheel makes fifteen revo-

lutions per minute and the emery wheel goes 256 times as fast as that. One pound of resistance at the emery wheel is like 256 pounds of resistance at the water-wheel. You notice the same thing when you use the saw or planer, or even present a chisel to a piece of soft wood in the turning lathe.

"The only machine here that it is important to keep running at constant speed is the dynamo. We shall probably notice the dimming of our lights at the cottage every time you saw a block or grind with the emery wheel or even polish with the felt buffer, because the speed of the dynamo will slacken for a moment and the voltage will drop a little."

In addition to sending electric current to the cottage the dynamo was to keep the battery stored all the time. Each machine had an appropriate motor attached to it which could run it by drawing current directly from the battery when the water-wheel was not running. Thus if one wanted to sharpen his pocket knife he merely closed a switch at the lathe and used the small stone, or if he wished to sharpen his lead pencil he put it in the lathe and applied a chisel to it.

These motors were all adapted to the 110-volt direct current and the battery contained fifty-seven cells, each cell being rated a little under two volts.

The boys frequently discussed possible combinations in this system. I spent a great deal of time loafing around among them in a comatose condition, and they talked quite as freely when I was around as when they were alone among themselves. One day I heard Dyne say, "Suppose we should store in a reservoir the water which comes down the penstock during a day and store all the electricity it will generate in a day in a storage battery, then at night let the battery run the dynamo backward as a motor, and that turn the water-wheel backward as a rotary pump, we should have the water in the upper reservoir to begin work with the next morning and the problem of perpetual motion would be solved.

"Aw, why do you want to do all that," said Erg, "when nature is doing it for us?"

Ernest said he had a better scheme than that. He would turn the battery current on to all the motors in the room and they would run the counter shafts forward and the counter shafts would run the dynamo forward and the dynamo would charge the battery, and so you could keep up the motion perpetually if you wanted to.

"Get out your pencils," said Harold, as he took down a copy of Houston and Kennelly. "Let us see how we would come out if we tried Dyne's prop-

osition for, say, twenty hours, storing the energy from the falling water for ten hours in the battery and then using this energy during the next ten hours for re-storing the water in the upper pond. We will say that the water-wheel furnishes eight horse-power for ten hours — eighty horse-power hours."

I notice it is stated in this book that small dynamos are usually unable to deliver more than 75 per cent. of the energy impressed upon them, and storage batteries and motors deliver about 80 per cent. of the energy impressed upon them. The accounts would, therefore, stand as follows:

Dynamo	*Horse-power Hours* *Dr.*	*Cr.*
To energy impressed by water-wheel	80	
By energy delivered to storage battery		60
By loss in heat		20
	80	80

(Assuming that the battery was able to receive all the dynamo could give.)

STORAGE BATTERY ACCOUNT

To energy impressed by dynamo	60	
By energy delivered back to dynamo running as motor		48
By loss in heat		12
	60	60

Dynamo Running as Motor	*Horse-power Hours*	
	Dr.	*Cr.*
To energy impressed by battery	48	
By energy delivered back to water-wheel		36
By loss in heat		12
	48	48

(This dynamo being a particularly inefficient motor.)

We cannot give the account of a water-wheel acting as a pump, because such a machine has not yet been perfected. It is evident however that if a water-wheel could be devised that should be a perfect pump, the losses in this chain of machinery are more than half; indeed, the accounts show them to be 60 per cent. We should, therefore, be able to return less than half the water drawn from the lake each day, and we should rapidly move toward bankruptcy.

"Well," said Ernest, "my proposition is more successful than that, because it sets out to be a fool proposition."

It was first suggested by the snake who undertook to swallow himself. Suppose the account does taper down from eighty to one, so does the snake, but he still remains "wise as a serpent." Our account would stand as follows:

Dynamo		Battery		Motors	
36	27	27	20	20	15
15	12	12	9	9	7
7	5	5	4	4	3
3	2	2	1	1	.8
.8	.6	.6	.48	.48	.36
.36	.27	.27	.20	.20	.15
.15	.12	.12	.09	.09	.07
.07	.05	.05	.04	.04	.03
.03	.02	.02	.01	.01	.003

It is evident that while our energy would dwindle continually we should never quite come out of the little end of the horn, since any number may diminish by 20 per cent. of itself indefinitely.

"Let us get at something practical," said Erg. "How are we going to furnish electricity to the cottage when the dynamo is not running? If we put a storage battery at the cottage, how are we going to store it having nothing but alternating current up there; and if we attempt to transmit current from our central station battery, how are we going to get along with the drop in the voltage?"

"I'll tell you how to do that," said Dyne. "They want 20 amperes and the line offers 4 ohms of resistance. That means a drop of 80 volts. We have simply to provide a subsidiary battery of 48 cells, which we may throw in series with our 57 cells when

we supply electricity to the cottage, and then they will have the right voltage for use out there."

"Yes," said Erg, as he rolled over, "they will have the right voltage when they use 20 amperes, but what will happen if they simply turn on one lamp. The drop in voltage then will be (.5 amperes $\times$ 4 ohms $=$) 2 volts; 105 cells at 1.8 volts a cell will send out there 189 volts minus the drop of 2 volts, leaving 187 volts upon a lamp adapted to 110 volts, and it will immediately burn out. The same thing would happen to any single piece of apparatus if the current was turned upon it alone. The only thing they could do if they wanted to light a lamp, say in the middle of the night to take a dose of medicine, would be to start up all together, all their lamps, sewing machine, wringer, dishwasher, fireless cooker, vacuum cleaner, etc., etc., to keep down the voltage so that one lamp would not burn out."

"I have read," said Ernest, "that they use rectifiers, which convert the alternating into direct current, for storing batteries. These are much used over the country. Electric automobiles run by storage batteries, and in the great majority of communities there is no other electric current than the alternating. So they would be helpless without

the rectifier. We should then get another battery of fifty-five cells for the cottage and keep it stored by using a rectifier with our alternating current.

"But all their equipment up there," said Ernest, "is adapted to the alternating current. Of what use would a direct current be to them?"

"Well," said Harold," it is all the same whether you have alternating or direct current on lamps, cooking apparatus, etc., and I have understood that they have motors which run on both alternating and direct currents. If so, that would fix them up all right."

The boys now turned to me for the first time to inquire whether motors could be obtained which would run on both alternating and direct current, and I replied that small motors for running sewing machines, vacuum cleaners, etc., were made which would serve us, perhaps not economically, but as they were the only solution to our problem we could get along with them.

"Why don't they have alternating current batteries?" inquired Erg.

"Well, it is time that we learned about the nature of batteries," said I, "if you boys are going to have two storage batteries to care for."

XIII

DOING CHORES BY ELECTRICITY

CHORES were my salvation in youth, and those chores were not trifles. I was made to feel that the whole family depended on my milking the cows, bringing in the eggs, keeping the wood box full of wood, the water pail full of water brought from the old well, churning the butter, feeding and watering the animals, and performing a multitude of regular daily and weekly tasks. As I grew older my responsibilities were allowed to increase proportionally so that I might feel some measure of the dignity of being a mainstay and a support of the family. Long before I reached manhood occasional opportunities were presented for me to play the full part of a man. These sometimes came during a temporary absence or sickness of my father, but more often, as I learned afterward, by his skilfully eliminating himself from the situation so that I might try my powers.

We attempt in the present generation to furnish

a substitute for the old time chores by our daily programme in school or in summer camp, but I often wonder whether this round of trifles can make men. Can one grow great without having a chance to feel occasionally that the world depends upon what he does?

The great advantage of Millville to us all lies in the fact that my wife is a good organizer. She immediately saw that the introduction of electricity into the cottage enabled her to assign chores to us all. These chores were assigned so that the establishment ran like clock-work. On Monday morning in a large room, called the wash room, she arranged the soiled clothes in five piles. Pile No. 1 contained sheets and pillow cases; No. 2, white shirts, shirtwaists, and other starched clothes; No. 3, underclothes; No. 4, towels, etc., and No. 5, coloured clothes. Here stood a washing machine run by electric motor and a wringer run by the same motor (Fig. 143). By the side of it sat a tub for rinsing water and next to that a tub for bluing water. Two boys placed a wash boiler over a two-burner oil stove, put five pails of water into it, and cut up one cake of laundry soap which they also put in. When this was boiling hot, about half of it was poured into the washing machine. The

other half was to take its place later in the washing machine. The first pile of clothes was put in and the motor run for five minutes. This batch was then run through the wringer into the rinsing water, and then again through the wringer into the bluing water, and then through the wringer a third time into the clothes basket, and hung upon the line out doors in the clear sunshine, which did more than all else to make them sweet and clean. A basket of such clothes from the line makes you want to plunge your face right into it and take a good whiff. There is nothing like it except a mow full of new hay. The piles of soiled clothes follow one another through

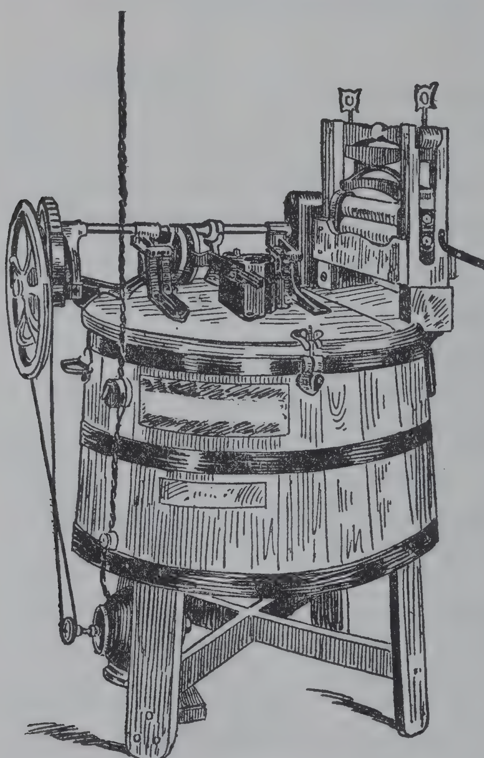


Fig. 143

this series of tubs on about a fifteen to twenty minutes headway, so that the whole family washing is done wholly by two boys inside of two hours. Each pile after the first is given ten minutes in the washing machine.

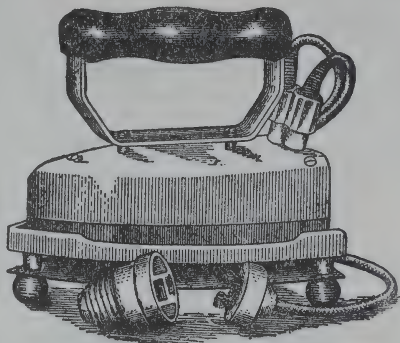


Fig. 144

On Tuesday the ironing is done with electric irons (Fig. 144). On Friday the house is cleaned by the vacuum cleaner, run by electricity (Fig. 145).

On Saturday a lot of baking is done in a series of fireless cookers (Fig. 146).

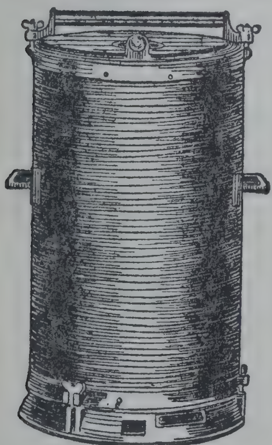


Fig. 145

The sewing machine runs more than ever before. I hear "It is such fun to sew with an electric motor." And the electric fan which Harold installed for his mother over the sewing machine "makes that the coolest spot in the house."

Chores do not take all of the time, nor most of the

time. They are simply the important things which must be done right on time. Meanwhile there is plenty of time for other things and a vast lot of experimenting goes on down at the mill.

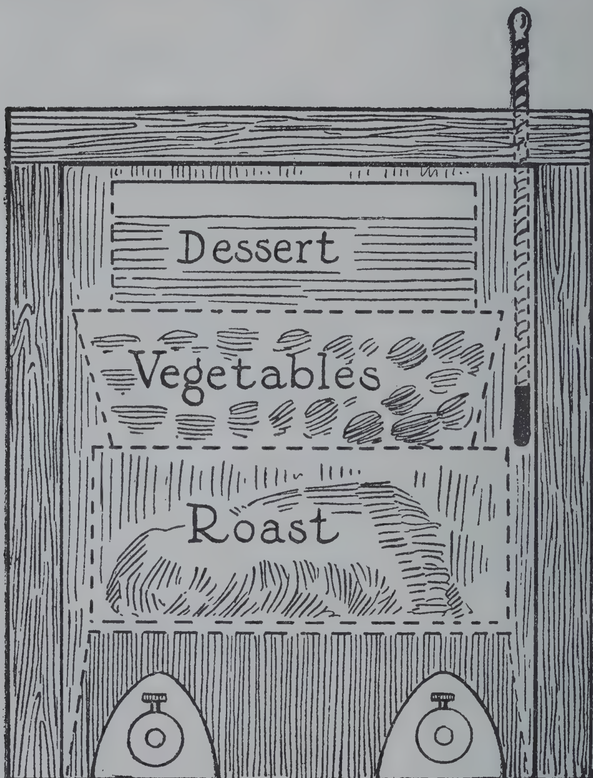


Fig. 146

It is my chief entertainment to stroll down there every day and look on. One day I found this project on trial: On the floor (Fig. 148,*f*) of the

room over the wash room at the mill a large dripping pan *A*, was set on blocks of wood so that one corner was lower than the rest. A rubber pipe, *B*, brought water to this pan from the mill pond, an inverted faucet, *c*, regulating the flow. The overflow from the pan fell into a funnel, *d*, the stem of which went

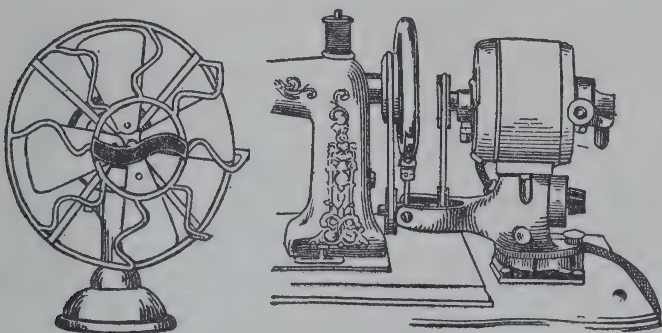


Fig. 147

through a hole in the floor. A short piece of rubber pipe connected this with the nozzle, *e*, of a gardener's sprinkling can, which hung from the ceiling in the compartment for the shower bath. Electric lamps attached to a board, *g*, were inverted over the pan of water, so that the bulbs of the lamps were immersed in the water. The electric current for these lamps was controlled by a switch, *h*, placed by the side of the water faucet. When one wanted a shower he could have it as cold or as hot as he chose by adjusting properly the switch and the faucet. Moreover,

it was not necessary for him to wait, for warm water flowed immediately.

In discussing this the boys said that a 32-candle-power lamp used 110 watts, and that since 96 per cent. of the energy supplied to the lamps went into heat each lamp transformed 105 watts of electrical

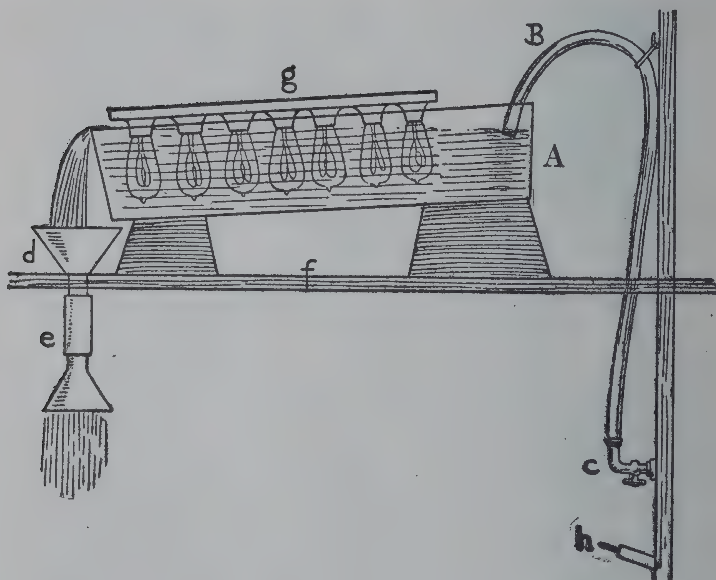


Fig. 148

energy into heat. But 100 watts sufficed to raise one pint (one pound) of water five degrees in one minute. They used seven lamps or about one horse-power, and adjusted the flow so that the shower delivered one quart of lake water per minute warmed for a tepid bath.

The next time I sauntered down to the mill the boys were working on what they called an electric shower bath. They had fastened upon the wall of the bath room an electric bell (Fig. 149), and placed on a shelf near by a battery of two dry cells, *P*. The switch which closed this primary circuit was on the wall by the side of the faucet and electric heating switch (Fig. 148). One of the wires, *S*, for the secondary circuit was carried up and connected to the pan *A* (Fig. 148). The other wire was fastened to a sheet of zinc about a foot square, which lay upon the floor of the shower bath. The idea was that when one was taking a shower bath, if he chose to vary his sensations he might step upon the sheet of zinc, close the switch in the primary circuit and let the secondary current pass through his body by way of the shower. They said that it was particularly prescribed for slow people.

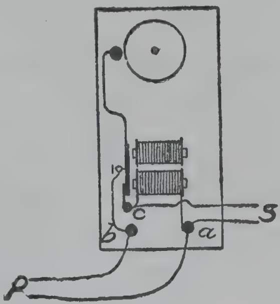


Fig. 149

Speaking of chores, of course the most insistent chore was to keep the storage batteries stored. This process gave rise to many questions, through which the information contained in the next chapter was brought out.

XIV

ELECTRIC CURRENTS FROM CHEMICAL ACTION AND CHEMICAL ACTION FROM ELECTRIC CURRENTS

LUIGI GALVANI (1737-1798) of Bologna, Italy, in 1786 unwittingly produced an electric current from chemical action. Because he was eagerly seeking other results he misinterpreted this. Several words in the dictionary are becoming either obsolete or misnomers. For example, galvanism is an old-fashioned word for an electric current. The expression *galvanic electricity* is a relic of the abandoned idea that there are several kinds of electricity, of which Galvani discovered one. Galvanized iron is wholly a misnomer. It is a name used for iron which has been coated with zinc, and it suggests the idea that somehow the zinc is coated upon the iron by means of an electric current, whereas in fact it is done by dipping the iron into melted zinc.

Alessandro Volta (1745-1827) of Como, Italy, took up the discovery of Galvani, interpreted it correctly, and perfected the method of producing

electricity by chemical action. What these two men really discovered was that it is possible to produce continuous currents of electricity. Before that electricity was known only by the instantaneous discharge or spark. From the name of Volta is derived the word volt, which designates the unit of electro-motive force. The adjective *voltaic* is synonymous with *galvanic*, as voltaic or galvanic cell, voltaic or galvanic current. For a long time it was thought that such an adjective was needed to designate electric currents generated by chemical action as a peculiar kind of electricity. We no longer think of electricity which is generated by chemical action as different from that generated by a dynamo or from any other source.

For about seventy-five years after the discovery of Galvani chemical action was our only method of generating currents of electricity, and it is largely owing to the inadequacy of this method of production that so few uses for electricity were discovered previous to the perfection of the dynamo about a third of a century ago. Two things have conspired to bring about this *age of electricity*. (1) The dynamo reduced the cost of production from five dollars to ten cents per kilowatt hour. (2) Mankind grew extravagant, greatly increased the number of things

which it considered necessary, and at length became both able and willing to spend more for the things which it demanded.

The so-called voltaic cell is of scarcely more than academic interest now. The school which, as a rule, follows half a century behind practical life, has taught and still teaches the philosophy of the galvanic cell with great particularity. It is now being urged to undertake the teaching of the dynamo. Meanwhile the dynamo has almost driven out of existence all electric battery cells except the storage cell and the so-called "dry cell," and each year the dynamo is encroaching more and more upon the territory of the dry cell. In the present day, when a passenger upon a street car pushes a button to stop the car, he uses, not a voltaic cell, but a 500-volt dynamo current to ring a small buzzer, and it costs the company not one-hundredth part as much as it would to furnish him a battery equipment to do the same thing. Small dynamos and magnetos are displacing dry battery cells in the sparking equipment of motor boats and automobiles.

We lifted a dry battery cell out of its pasteboard case and found that it was contained in a metal cup of sheet zinc. The top of this was sealed over airtight with pitch, the purpose of which is to

prevent this "dry" cell from drying up. We dug away the hardened pitch and found a black powder which was distinctly moist. In case the pitch becomes cracked or a hole appears in the zinc cup, the moisture passes out and the cell ceases to act as a generator of electric current.

The zinc cup had a lining of pasteboard on the sides and the bottom, similar to the pasteboard which enveloped the outside, only the lining was quite moist. A corrugated rod of carbon about an inch in diameter occupied the middle of the cup, and the space around it was packed full of a mixture of ammonium chloride, manganese dioxide, and other substances like plaster, etc., which differ with different cells. A dry cell which has been long in use is quite apt to show stains upon its pasteboard case. These are caused by holes which appear in the zinc. The production of electric current by the cell is dependent wholly upon a chemical action between the zinc and the ammonium chloride which results in the destruction of both. This chemical action cannot go on without moisture.

The zinc cup of the particular cell which we were examining appeared to be intact, and we proceeded to dig out the black powder. Its black colour is due to the manganese dioxide. Ammonium chloride

is white. We lifted out the carbon rod and scraped the zinc cup clean. The binding posts attached to both the zinc cup and the carbon rod were left intact. Into the zinc cup we now poured a tumblerful of water and added about a quarter of its volume of hydrochloric acid, setting the whole into a large bowl to guard against disaster. Bubbles of gas were formed rapidly, causing the liquid to effervesce as a tumbler of soda water would do. We inverted an empty tumbler over the cup so as to collect this gas. In about two minutes we lifted the tumbler, still holding its mouth downward, and brought a lighted match to it. There was a flash and the contents burned with a pale-blue flame. Some of the zinc had united with some of the hydrochloric acid and set free hydrogen gas, which is one of the constituents of the acid. This is typical of chemical actions. Something similar takes place between the ammonium chloride and the zinc. Three interesting things occur in this experiment:

1. Chemical action, just described, is produced.

2. Heat is produced. This was very evident when we took the zinc cup up in our hands. It was as hot as though boiling water had been put into it.

3. An electro-motive force is produced. This we

showed by connecting one end of a piece of copper wire to the binding post of the zinc cup and the other end of the wire to an electric bell. Another wire ran from the bell to the carbon rod. When the carbon rod was lowered into the acid the bell rang.

Within ten minutes holes began to appear in the side of the zinc cup. The acid contents began to flow out into the bowl, and not long after the zinc fell to pieces. After fifteen or twenty minutes the action began to grow less. The acid was being used up as well as the zinc. If enough acid is added the zinc will wholly disappear.

We have chosen substances which would produce striking results in this experiment, but the same sort of thing is going on about us continually.

One summer by the seashore I fastened a brass plate upon my boat with two screws— one of brass and one of galvanized iron. The plate was attached below the water line so that it might be acted upon by the salt water. Within three weeks the head of the galvanized iron screw had entirely dissolved, while the brass screw was as good as ever. A galvanized iron screw near by but not in contact with the brass was still in as good order as ever. I had simply made an electric battery cell out of the ocean by dipping into it zinc and brass in contact.

A most interesting relationship exists between the three kinds of activity in the cell, which have been mentioned, viz.:(1) chemical action;(2) production of heat;(3) production of electric current.

As has been already noted, chemical action produces heat. Conversely, if we apply heat to the cell we greatly increase its chemical action. We have also noted that chemical action produces an electric current, but unless the current is allowed to flow through some external channel like a closed circuit of wire the chemical action is greatly restrained or entirely checked.

In a glass tumbler I put a rod of pure zinc (Fig. 150, *Zn*), and an electric light carbon, *C*. A short wire, *a*, was arranged for connecting the two externally. In the tumbler was put some water with about one tenth its volume of sulphuric acid. No chemical action was evident until the wire was touched to the zinc, closing the circuit. Then bubbles of hydrogen gas gathered upon the surface of the carbon rod, and clung to it very tenaciously. We lifted out the carbon rod and rinsed off the bubbles in another tumbler of

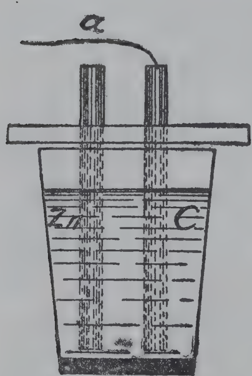


Fig. 150

water, and then returned the carbon to its place in the cell. The experiment was repeated many times, and each time no bubbles of hydrogen, which is in this case the sign of the chemical action, appeared until the circuit was closed for the flow of the electric current. Incidentally it should be said that the amount of hydrogen produced by the chemical action is a measure of the amount of electric current produced. Incidentally also it should be said that the bubbles of hydrogen clinging to the carbon rod check and almost stop both the chemical action and the production of electric current when the circuit is closed. If now we put in sodium bichromate to use up the hydrogen as fast as it is produced we may have a continuous current whenever the circuit is closed. Chemical action does not entirely cease in this cell when the circuit is opened. But if two cells are prepared, and one is left with its circuit closed while the other remains with its circuit open, it will be found that the zinc disappears and the acid is used up in the closed cell in a short time, while these remain not greatly changed for a long time in the cell on which the circuit is open. No cell will remain forever without chemical action, yet a dry cell which might use up its zinc and ammonium chloride in a few hours

if the circuit is closed may be kept idle three or four years, and still be able to furnish electricity enough to ring a bell. Some persons feel defrauded if the author of a book fails to give them all the new words and conventional terms which belong to any subject. For such here is a page or so.

It is conventional to speak of the electric current as flowing from the carbon through the wire to the zinc, although every one has suspicions that it may flow in the other direction or even that it may not flow at all. It is conventional to designate any part of the circuit from which the current comes as positive (+) to any other part toward which it flows, this latter being considered negative to the former and designated (—). The current is conceived of as making a complete circuit, from carbon to zinc through the wire and from zinc to carbon through the liquid. Hence, the binding post of the carbon rod is called the + pole and that of the zinc is called the — pole, while the zinc rod or plate beneath the surface of the fluid is called the + plate and the carbon is called the — plate. The liquid is termed the electrolyte. The sodium bichromate, introduced to cause the hydrogen to unite with oxygen, is called an oxidizing agent or even a *depolarizing* agent, and hydrogen collecting

upon the negative plate is said to polarize the cell.

Hydrogen may be made to collect upon the carbon or negative plate until the electric current reverses its direction. The hydrogen is said to be more — than the zinc. If we connect the zinc and carbon rods with the wires bringing an electric current from the dynamo we may make either one positive as we choose, according to which is connected with the positive wire. Hydrogen bubbles will collect upon whichever plate we make the negative one.

When we send an electric current from the dynamo into this cell it is called an electrolytic cell, and when it is used to generate an electric current it is called a battery cell. In either case the electrolyte is decomposed and put through a chemical change, though the chemical action in one case is the reverse of that in the other, and the direction of the electric current in one case is the reverse of that in the other. For example let us consider the case of a zinc rod and a carbon rod immersed in sulphuric acid and the external circuit closed. The current passes as indicated by the arrows in Fig. 151, and the chemical actions result in hydrogen leaving the sulphuric acid and zinc taking its place, forming

zinc sulphate. This is a white salt and for purposes of this experiment must remain dissolved in water. So far we have been considering a generator of electricity — a battery cell. We may introduce something at *m*, say a motor, which will indicate that an electric current is flowing. At length the cell ceases to generate current and is, as we say, "run down." Suppose now we substitute a dynamo in place of the motor in this circuit, connecting it so that the carbon rod shall be its positive pole and the zinc its negative pole. We now call this an electrolytic cell, (Fig. 152). The current will decompose the zinc sulphate. The zinc will be coated upon the zinc rod and hydrogen will be procured from the water present, of which it is a constituent, to form again sulphuric acid as originally.

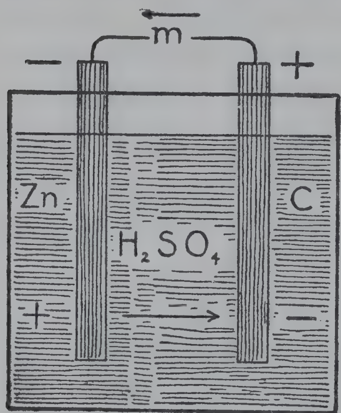


Fig. 151

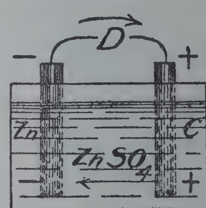


Fig. 152

We shall thus restore the conditions which prevailed in the first case as represented in

Fig. 151. H_2SO_4 is the chemist's designation of sulphuric acid and $ZnSO_4$ is his expression for zinc sulphate.

The experiment illustrates a storage battery so called. It might better be called a chemical transformer.

It is wholly unnecessary that one rod be composed of zinc. If we begin with both rods of carbon immersed in a solution of $ZnSO_4$, and send into this cell the dynamo current, the carbon which acts as the negative pole will be coated with zinc in a short time, and we shall have in effect a rod of zinc and one of carbon as before. After a minute or two we may disconnect the generator and substitute in its place a bell as indicator, and it will ring, showing that we have transformed electrical energy into chemical energy which is now being retransformed into electrical energy. We say that we store electricity by this means, which is, however, no more true than that a farmer stores his farm in the bank when he sells it and deposits the money until he shall need it to buy another farm.

Here is a very beautiful blue salt. I will drop a few crystals of it into a tumbler of water and dip in two carbon pencils connected to the dynamo current, using between fifty and sixty ohms of re-

sistance in the circuit so as to have two amperes flowing. After a minute or two I lift out the negative carbon and you see that it is well plated with copper. The blue salt is copper sulphate. If we weigh the negative carbon, both before and after the experiment, we shall find that copper has been depositing at the rate of one ounce in twelve hours. If we reduce the current one half, making it one ampere, it will deposit copper at the rate of one ounce in twenty-four hours. One ampere will separate three ounces of lead in a day from a solution of any lead salt; it will separate .9 ounce of iron in a day from a solution of any iron salt, and it will liberate from water, which is a compound of hydrogen, one gallon of the gas in ten hours. The amount of chemical action is a measure of the amount of electrical energy expended. Before the present form of commercial watt-meter was devised electrolytic cells were used to determine what the consumer's bill for electricity should be each month. These chemical meters contained a solution of zinc sulphate for the electrolyte and both the positive and the negative plates were of zinc. While the current is passing, zinc from the solution is coated upon the negative plate and zinc from the positive plate takes its place in the solution, thus maintaining a constant strength of solution.

Here are three iron nails. I propose that you plate one with zinc and another with copper and then expose all three to the weather and see which will rust. I propose that you replate all the spoons at the cottage and the metal tops of the salt cellars with silver. Electro-plating results better if done slowly. Ten volts and .1 ampere will be sufficient current.

In the storage battery we generally use lead for both positive and negative plates and dilute sulphuric acid for the electrolyte. Hydrogen is liberated at the positive plate and oxygen unites with the negative plate. When the charging current is cut off the chemical action reverses, and an electric current is produced by the cell.

In all other batteries there is a destruction of one plate and of the electrolyte, which cannot be fully restored by a charging current, although in the case of the lead and sulphuric acid combination the charging and discharging of the cell may go on alternately for a very long period without permanent change or loss of any substance except water. There is, however, plenty of loss of energy in this as in other transformers. One hundred ampere hours of current expended to charge a storage battery will yield from seventy-five to eighty-five ampere hours while the battery is discharging.

The lead storage battery is, however, full of disappointments for those who do not properly care for it. It is irretrievably ruined if neglected and allowed to charge too far, or discharge too far, or evaporate too much water, etc. The voltage of a lead cell must not rise above 2.2 nor fall below 1.8. It must not be allowed to furnish at any one time a greater number of amperes than it is rated for. It must not stand idle too much. It must not be cleaned up and put away for a period. In fact, the lead-sulphuric acid battery is so poorly adapted to our need that I feel disposed to try Mr. Edison's new storage battery. This has nickel hydrate packed in tubes of metallic nickel for the positive plates and iron oxide pressed into pockets in a sheet of metallic iron for the negative plate. A solution of potassium hydrate in water is used for the electrolyte. This is said to be uninjured by being emptied out and left idle, as our batteries must be for a large part of the year. The e. m. f. of this battery is less than that of the lead battery, being only 1.2 volts. We shall therefore need ninety-six cells (type *B-4*) for the machine shop and ninety-one cells of the same kind for the cottage. Our dynamo will be unable to charge at one time more than sixty of these cells connected in series.

The particular chore which you boys must perform is to see that the voltage of these batteries is maintained at about 1.2. It should be charged up to 1.8 volt at least once a week and never allowed to discharge to a lower pressure than one volt. The level of the electrolyte must be maintained one half inch above the plate by adding distilled water occasionally.

A few years ago every student of chemistry was more or less agitated by the thought that more than half of every clay bank was composed of metal nearly as valuable, or at least as costly, as gold. This is aluminum. By all the methods then known it was a very difficult and expensive process to extract the metal from the clay. At length, by the perfecting of the dynamo, the chemist had under his control great and powerful electric currents which enabled him to unlock any chemical compound however refractory and isolate its elements. As a result aluminum became common enough and cheap enough for even kitchen utensils.

The metal calcium which a short time ago was an exceedingly rare substance worth $40 an ounce is now fairly abundant and cheap for chemical experiments, although it has no qualities which will give it an extended use.

Powerful electric currents, such as are obtained at Niagara, enable us to combine elements into hitherto unknown chemical compounds. Carbon and silicon are made to unite to form carborundum, which vies with the diamond for hardness. Carbon and calcium unite to form calcium carbide, used with water to form acetylene gas.

In such processes the intense heat of the electric arc — perhaps 6000 degrees — is employed, together with the electrolytic action of the current, to separate and combine substances. Enormous currents are used in the electric furnaces for producing chemical reactions — from 1000 to 30,000 amperes at a time.

Electric currents passing through the human body expend their energy partly in heat and partly in electrolysis. So simple and harmless a thing as common salt would become a virulent poison if it could be electrolized in the body into its elements *sodium* and *chlorine*.

Let us make use of an electric current to decompose water into its elements, hydrogen and oxygen. I have a three-ounce wide-mouthed bottle (Fig. 153) and through its cork I pass two short pieces of No. 24 platinum wire by pushing a stout needle through first. I fill this bottle with pure water and cut

a slight furrow in the side of the cork, where water may drip out when the gas is produced in the bottle. We crowd the cork firmly into the mouth of the bottle and invert it. No water drops out. We bend the ends of the platinum wires into hooks and hang upon them the wires bringing the dynamo direct current. There is no evidence of chemical action. Pure water is an exceedingly poor conductor of electricity. Let us now put about fifty-five ohms of resistance into the dynamo circuit, so that it will pass about two amperes, and put a very small pinch of salt into the water, which makes it so good a conductor that its resistance may be ignored. When now we close the circuit, as before, a brisk effervescence takes place. Bubbles of gas rapidly form on the platinum wires and break away, rising through the liquid. Twice as many form on the negative wire as on the positive one. As these gases rise to the top of the bottle an equal volume of the water drips out through the small hole in the cork.

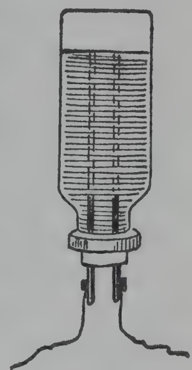


Fig. 153

Two amperes of electricity will liberate two fluid ounces of hydrogen at the negative pole and one

fluid ounce of oxygen at the positive pole, in five minutes. Hence in five minutes the bottle should be full of a mixture of two gases, two thirds of which, by volume, is hydrogen and one third oxygen. We will catch the water which drips out so that we may measure it. The bottle being now full of gas I shut off the current, and removing the cork I bring a flame to its mouth. A very loud and startling explosion takes place. We pour the water back into the bottle, and it seems to fill it as well as before. We have decomposed a few drops of water — not enough to measure — into two gases, one of which, the hydrogen, occupied two thirds of the bottle, and the other, oxygen, occupied the remaining third. At ordinary temperatures they would not reunite, but when raised to their kindling temperature they united, producing light, heat, a loud noise, and the few drops of water which had been originally decomposed by the current.

This is the electrolysis of water. I wonder if any such chemical action took place in Ernest's body when he received that severe shock on the motor boat the other day.

It is significant that the "dry" battery cell must be moist in order that chemical action may go on in it. Compare with that fact several others that

we may learn from observation, for example: Baking powders must be kept dry to retain their strength. That is, if they get moist chemical action will begin in them, and the gas which is one of the products of this chemical action will pass off. Now it is the sole function of baking powders to produce gas within the dough, and if the gas has wholly or partially escaped they will fail to make the bread stuff "light." The same reasons obtain for keeping seidlitz powders and other effervescing salts, such as vichy and kissingen, dry. It is to prevent the chemical action which is provoked by the presence of water. The same thing is true of the rusting of iron, and the various kinds of corrosion of metals. We may prevent such action indefinitely by keeping them dry. Berries, fruits, meats, milk, eggs, grain — all kinds of foods — are preserved from spoiling — from chemical changes — by drying them and keeping them dry. The same thing is true of wood, paper, cloth, etc. A wooden fence post may last from five to ten years. A fence rail, being less exposed to moisture, may last two or three times as long. The interior wood of a house may last a century or two, while the exterior wood, being exposed to the weather, may require repairs very frequently. Shingles on the roof do not last as

long as shingles on the side of the house. Those on a steep roof last longer than those on a flatter one. A pitch of at least forty-five degrees in a roof is desirable to keep it dry. The north and west sides of a house being least exposed to storm in this climate last the longer. Precious books, records, deeds, wills, etc., on paper must be preserved in dry air. A sail will keep strong and white if kept dry.

But it is impressed upon us by our experiences that sunlight is even more potent than moisture to produce chemical change. Photographic processes are dependent upon the power of light to produce chemical changes. The fading of our tapestries and our garments, the tanning of our skins, the development of green material in the leaves of plants, all are evidently the direct result of sunlight. A picture hung on the wall prevents the wall paper behind it from being faded by the light, or it prevents the wood behind it from being turned yellow by the light. Folds in our garments prevent them from being faded all alike. Very many substances to be found in a chemical laboratory, in a drug store, or in a kitchen must be kept in the dark if they are to be guarded against chemical change. No experienced housewife would let a

barrel of flour or potatoes sit in the sun, and every housewife knows that the sun is the best agent for bringing about those chemical changes which she desires. Hence she puts her bedding, her milk pans, her bread box, her butter jar, etc., "out to sun." She has open plumbing, that the sun may enter those dark and dirty corners.

If you would guard a substance against chemical change, keep it in a dry, dark place. We have come to associate the sun and the weather as disintegrating forces. Hence the south and east sides of the building need most frequent repairs. Every one who has made time exposures in photography knows that the sunlight from the east is, as a rule, two or three times as powerful as that from the west. There is less moisture and dust in the air to screen us from the early morning sun than from the late afternoon sun. When there is enough moisture in the air to make the sun look red, those rays from it which would produce chemical action, called actinic rays, are cut off. Photographic processes are then exceedingly slow. It is like exposing a plate in a dark room behind the ruby glass.

But our daily experiences teach us that not only moisture and light but also heat stimulates chemical

action. We restrain chemical action by cold when we put things in the ice box. We hasten chemical action by heat when we put things on the stove. Winter restrains all the chemical activities of nature, and summer quickens all the vegetable and mineral kingdoms into chemical activity. If we would preserve a substance from chemical change we must keep it in a *cool, dark, dry* place. Now those conditions which will favour the chemical activity of a battery cell will enable it to produce electricity, and those conditions which will restrain chemical action will enable us to preserve the cell from running down.

But we have lately learned that other forms of radiation besides light and heat exist and aid in chemical action. We may produce radiographs — pictures on photographic plates — without light but with invisible rays, which are akin to light and to electricity.

XV

ELECTROCUTION AT MILLVILLE

THE old mill was infested with rats. My wife laid down to the boys the principle that good housekeepers were never troubled with vermin of any kind. The rats' sole occupation is to search for food. If you don't feed them they will not stay with you. But the boys said that they were glad of a chance to try an experiment on the rats. So one day when I went down to the mill I found them discussing the possibility of killing the rats by electricity. Harold said that he had read that it took much less electricity to kill any animal than to kill a man, and he would like to try, for instance, whether the shock which they had received from a bell would kill a rat.

"Well, who's going to sit by," said Erg, "to close the primary circuit when the rat happens to get himself into the secondary circuit?"

"Make him close it himself by some device," said Ernest.

"They have a regular thoroughfare, a beaten

highway, along by the wall, under the mill and up through a hole in the floor of my bedroom," said Dyne.

"Well," said Harold, "I propose an electric trap which shall have two compartments. We will keep cheese in the inner compartment, the walls of which shall be of wires so that the rats may see the cheese. The floor of the outer apartment shall be covered with wire, as shown in Fig. 154. The wires of the secondary circuit from the bell (Fig. 156) shall be fastened to the binding posts *b* and *c* (Fig. 154). The partition *d* shall be a swing door into the apartment *A* where the cheese is. This is shown in profile in Fig. 155. *d* must act as a switch to close the primary circuit through the bell *P* (Fig. 156). We will have three dry cells in the primary circuit. Now this is the way it will work: A rat comes up from under the mill with wet and slimy feet—just suited for making contact for the electric current to enter his body. The smell of the cheese attracts him. He circles around the trap several times, watching the cheese in apartment *A* through the

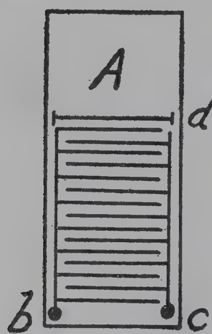


Fig. 154

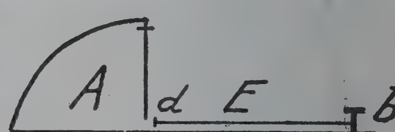


Fig. 155

wire screen. He sees a narrow opening into this apartment under the door *d*. He puts himself in position upon the floor of the outer apartment *B*, his feet bridging the gaps between the two systems of wires belonging to the secondary circuit. When he thrusts his head under the door and pushes it, it swings in a little, bringing one metal strip against another, which belongs to the primary circuit. This closes that circuit. He will never hear the bell ring, for the electric current which will shock him to death travels 186,000 miles per second, while his sensations travel only sixty miles an hour. If the involuntary recoil of his muscles does not make him jump back, so that the door will shut and stop the bell from ringing, Dyne will be awakened and he will close the door, since we will put the trap at that hole where the rats enter his bedroom."

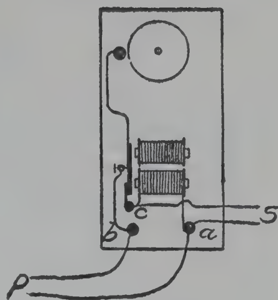


Fig. 156

The next night three rats were electrocuted by this device.

I told the boys they had so many interesting things going on at the mill that we should have to have a telephone between it and the cottage so that we could talk them over.

XVI

THE TELEPHONE

THE telephone was the great invention of our centennial year, 1876. Elisha Gray and Alexander Graham Bell each claimed to have been the inventor. It is quite probable that each did discover it independently, but the result of the long patent suit was that the court awarded the claim to Bell. It is, therefore, known as the Bell telephone.

Many who installed telephones during the first few years of their existence had them taken out again as nuisances. They are far greater nuisances now than at that time, but the necessity of them has come upon us and entirely enslaved us.

There were more than eleven billion messages sent by telephone in the United States in 1907. The capital invested in telephone business was \$814,616,004. The income for that year was \$184,461,747. All of these items had more than doubled during the previous five years. In 1880 there were about eight times as many miles of

telegraph wires as of telephone wires. In 1907, there were about eight times as many miles of telephone wires as of telegraph wires. The Bell system had 3,132,063 stations, and independent companies had 2,986,515 stations in 1907.

The first telephone line ran from Salem to Boston, Mass. This was in 1877. The next year the first telephone exchange was established. It was eight years before a telephone line was extended from Boston to New York. On October 18, 1892, the first telephone message was sent from New York to Chicago. Previous to 1895 telephoning, like telegraphing, was done by one wire, using the earth, as we say, to complete the circuit.

But at about that time electric car and electric lighting lines became so common that they interfered with telephoning. These currents running in lines parallel to the telephone wires induced currents in them, and when a person put a receiver to his ear for conversation he heard the hum of electric light dynamos and the buzz of electric cars so loud that conversation was quite impossible. The next step was to introduce a return wire — the double metallic circuit as we call it. Thus outside currents induce equal and opposite currents in the two wires of the circuit, which neutralize each other.

It was this same year, 1895, that the "central battery" system was introduced into telephone equipment. This is not usually a battery at all, but a dynamo.

The price of all electrical supplies in 1895 was about one tenth what it had been in 1885, and at the same time the goods were of far better quality.

Important telephone patents expired in this year, and immediately private and independent lines began to be established. It was also in 1895 that the telephone company began to use an automatic registering device which enabled it to charge telephone rates according to the number of calls.

The boys unscrewed the end of a telephone receiver (Fig. 157) and found inside a permanent magnet made of several steel bars bolted together (Fig. 158). This was shown to be a magnet by presenting a small pocket compass to either end. The left-hand end of this magnet proved to be its north pole by repelling the blue end of the compass needle.

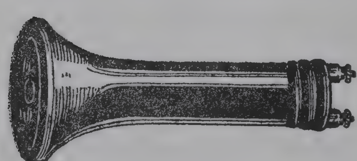


Fig. 157

On the left-hand end of the magnet was a small spool of No. 36 copper wire, silk covered. It offered

75 ohms of resistance, and since it takes 2½ feet of this wire to furnish 1 ohm of resistance the spool contains 187½ feet.

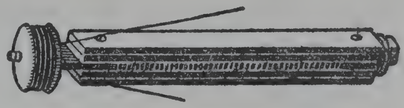


Fig. 158

A thin disc of soft iron .01 inch in thickness is held by the hard rubber case very near to but not quite touching this end of the magnet. We drew this disc to one side, as shown in Fig. 159, and connected the receiver by wires to a magneto. We turned the crank of the magneto slowly and the iron disk danced up and down, keeping time with the revolutions of the armature.

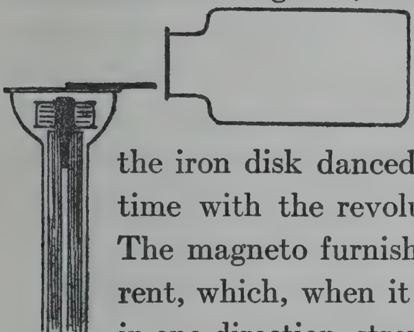


Fig. 159

The magneto furnished an alternating current, which, when it flowed around the coil in one direction, strengthened the pole of the magnet, and in the reverse direction weakened the pole. When the crank was turned so as to produce twenty to thirty revolutions of the armature per second the dancing of the disc sounded like the low hum produced by the wing of a humming bird. When a large, wide-mouthed bottle was brought near to this the sound was greatly reinforced, as the sound of a bee becomes louder when he appears at your open window. We next replaced the iron disc and

put on the cap again. We then connected the receiver at S (Fig. 160) and connected two dry cells at p. When the primary circuit was closed the disc vibrated in time with the hammer of the bell making the same tone. We substituted for the bell a series of buzzers. The smallest had an armature about one inch long, while that of the largest was about two inches long. The shorter the armature the faster it vibrated, and the higher was the pitch of its tone. We arranged these as shown in Fig. 161. A, C, D, E and F are the buzzers. B is a battery of two cells and G, H, I, J and K are springs of sheet

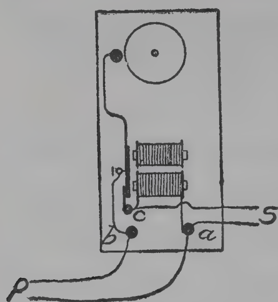


Fig. 160

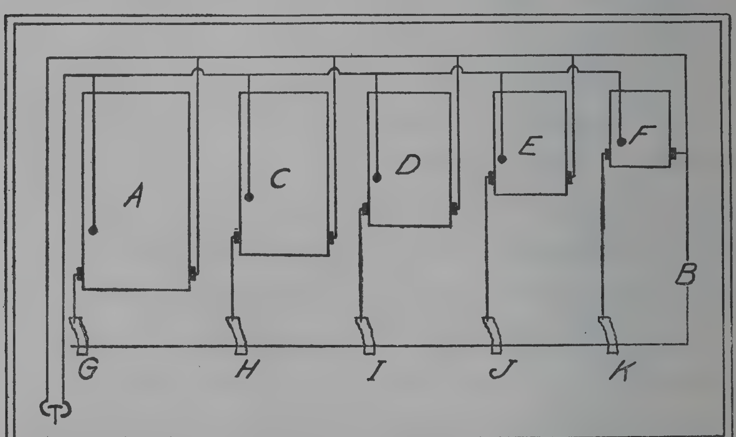


Fig. 161

brass which act as push buttons. By operating upon these springs with one's fingers, as upon the keys of an organ, it was possible to represent the tones of a reed organ after a fashion. The armatures are reeds and they are made to vibrate by electro magnets. We called it an electric organ. The telephone receiver was connected at T, and the wires which led to it were lengthened so that the receiver might be a long distance away. The disc in the receiver kept time with the armature of each buzzer when it sounded and faithfully reproduced its sound. But the strangest thing was that when any two buzzers sounded together, or, indeed, if all five buzzers sounded together, the receiver responded to them all at the same time, so that a person in another room or in another house, with the receiver at his ear, might hear exactly what those did who were in the same room with the buzzers. The wires from the receiver were connected with the coil in each buzzer so as to get the induced current, as shown in detail in Fig. 160.

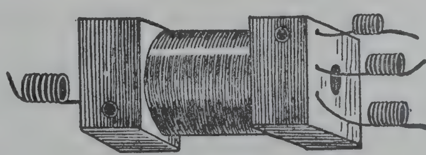


Fig. 162

We took a telephone induction coil (Fig. 162) and fastened it to a board as represented in Fig. 163, *I*.

One wire of the primary circuit was fastened to the binding post *a*. The other wire from the primary coil passed to the switch *S* and then to the battery. From the battery the wire ran to the binding post *b*. *C* is a steel tuning fork. The secondary circuit is closed through a telephone receiver. These wires are extended so that the receiver is too far distant for the tuning fork to be heard through the air. When the switch *S* is closed the tuning fork acts as the interrupter for the primary circuit, and it interrupts according to its time of vibration. If, for instance, the fork gives the tone of middle *C* on the piano it vibrates 256 times a second. It interrupts the primary circuit 256 times a second. It induces an alternating current of the same frequency in the secondary circuit. The diaphragm of the telephone receiver vibrates in perfect time with the tuning fork and produces the same tone as the tuning fork. We had a series of tuning forks giving a variety of tones, which we could substitute one after another in place of this one. The re-

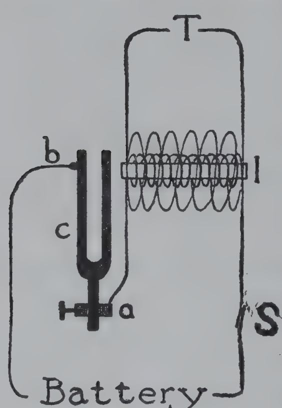


Fig. 163

ceiver reproduced accurately the tone of each one of them.

We took a small induction coil (Fig. 164) *c* and fastened one end of the primary circuit to a battery, *B*. The wire at the other end of the primary circuit was bent into a hook *h*. This hook was adjusted about a quarter of an inch from the end of the iron core of the coil. The other wire from the battery was attached to the steel strings of a piano, *P*.

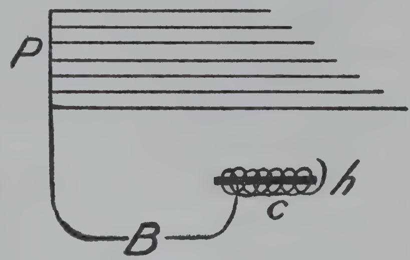


Fig. 164

When the coil *c* was brought over a string and the hook *h* was allowed to pass beneath the string and touch it very gently, the primary circuit was closed through the string, which served as an interrupter of the current and vibrated according to its tone. The secondary coil, not represented in the figure, was connected to a distant telephone receiver, which reproduced the tones of the piano strings.

Producing a tone is merely a matter of making something vibrate with the required frequency. It may be a piano string, or a tuning fork, or a reed of an electric buzzer, or the diaphragm of a telephone receiver. If it vibrates 256 times a second, it will

produce the same tone as middle *C* on a piano; if it vibrates 512 times a second it will produce the *C* which is an octave above, and if 128 times a second an octave below middle *C*. The human voice is produced by vocal cords in the throat, which vibrate with the proper frequency to give any required tone. But how can we make the human voice act as an interrupter of the primary circuit? An examination of the telephone transmitter will supply the answer to this question.

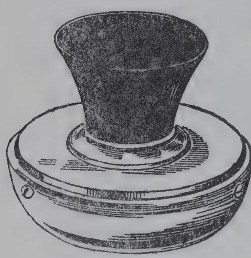


Fig. 165

The boys after taking the transmitter (Fig. 165) apart proceeded to make one which should answer the purpose as follows: A block of wood about one inch thick and three inches square (Fig. 166), *A*, was hollowed out, making a cone-shaped cavity about one half inch deep and one inch broad. This cavity was filled with small pieces of graphite, *G*, made by cutting up a lead pencil. An old

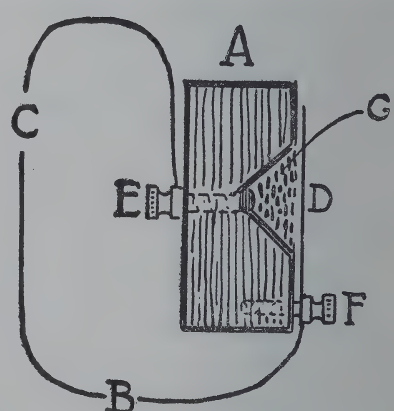


Fig. 166

tin-type, *D*, was laid over this as a diaphragm and tacked around the edges. A binding post, *E*, passed through the block, its head being buried in the graphite at the bottom of the cavity. The binding post *F* furnished contact with the tin-type. One dry cell was placed at *B* and the sensitive ammeter was connected at *C*. The needle showed that although a small current was passing it was constantly varying in strength. Tapping upon the table, walking across the floor of the room, shouting, and particularly whistling, caused variations in the conducting power of the graphite and consequently variations in the current

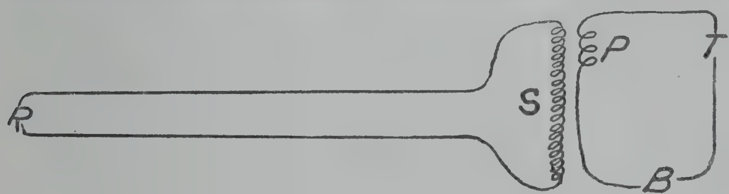


Fig. 167

strength. This is precisely the condition we wished to produce in the primary circuit.

We next substitute for the ammeter at *C* the primary and secondary coil of the telephone. In Fig. 167 *T* is the transmitter, *B* is a battery of two dry cells, *P* is the primary winding of the coils, and *S* is the secondary winding. To this a telephone re-

ceiver, R is connected by wires long enough to reach into another room. A person holding the receiver at his ear could hear everything said or done in the room where the transmitter was almost as plainly as though he were present in the room.

Two such transmitters were made and the second one was placed in the room where the receiver had been, while a second receiver was installed near the first transmitter. The arrangement is shown in Fig. 168. T is the transmitter at one end of the

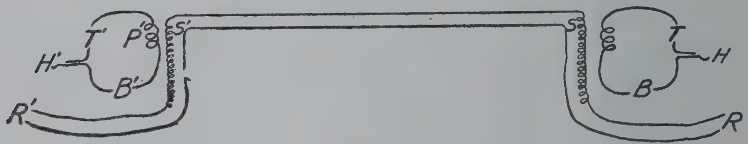


Fig. 168

line and T' the transmitter at the other end. B and B' are the batteries at each end, P and P' the primary coils, S and S' the secondary coils and R and R' the receivers. With this arrangement two persons carried on a conversation with perfect ease, holding the receivers to their ears, presenting their mouths to the transmitters and speaking in moderate tones. H and H' are hooks upon which the receivers are to be hung when not in use. These hooks act as switches to open and close the primary

circuit. A spring normally pushes the hook upward and closes the circuit, but while the receiver is hanging upon it the circuit is open at this point. Thus the battery is saved from running down when the telephone is not in use.

The wires were finally extended from the mill to the cottage and this equipment was installed at each end.

It will be noticed that the secondary circuit includes two receivers and two secondary coils besides the wire of the lines to offer resistance.

The receivers offer 75 ohms of resistance each. The secondary coils offer 250 ohms each and the line wires between the mill and the cottage offer 100 ohms. This makes a total of 750 ohms for the secondary circuit. But the rapid alternations which are induced in the secondary circuit impede the electric current ten times as much as the resistance already mentioned.

When considering alternating currents passing through coils of wire we are obliged to take into account two kinds of resistance:

1. Ohmic resistance.
2. Impedance.

"You boys understand the resistance to the flow of the electric current, which we have so often mea-

sured in ohms. But I want to show you that there is another kind of resistance which alternating current meets. Here is a coil containing 1000 feet of No. 20 copper wire. I throw on to it, for only an instant, the 110-volt direct current, and the ammeter reads 11 amperes, showing that it offers a resistance of 10 ohms to the direct current. I now throw on the alternating current, and the ammeter shows only a small fraction of an ampere. The surging of the current back and forth induces a counter electromotive force, in the successive layers of the coil, which we call *impedance*. In the experiment which we have just performed *impedance* is fifty times as important a factor as ohmic resistance. Impedance depends chiefly upon the frequency of alternation. The impedance in telephone circuits is particularly large because of the extremely high frequency of the alternations produced by the tones of the human voice, these being usually not far from ten times as rapid as those of alternating currents in common use.

"We may estimate the total resistance of our telephone circuit as equivalent to 7500 ohms.

"Our secondary coils have forty times as many turns as the primary coils, and by means of them the voltage is stepped up to somewhere near one

hundred on open circuit. When closed through the line, however, the voltage drops down to about ten. The result is that the actual current which passes between the cottage and the mill when we telephone is not far from .001 ampere. We may, however, hear a whisper transmitted by .000001 ampere or less.

"The tone *E'* which is produced by the tenth key above middle *C* on the piano, is the one most readily heard over the telephone. It is produced by anything which vibrates 640 times per second."

We used No. 12 galvanized iron wire for our telephone lines. Two miles of No. 12 copper wire would offer 16 ohms of resistance. The iron wire offers about 100 ohms. But this is a trifle

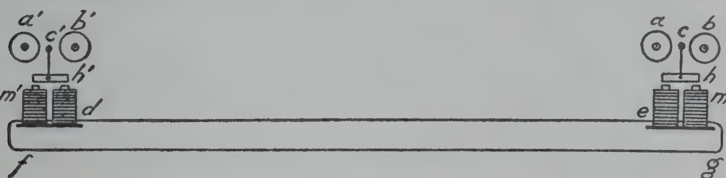


Fig. 169

when compared with the total resistance. We used a double metallic circuit so as to avoid the effects of inductance from our electric lighting circuit.

The next thing that we were obliged to consider was some arrangement for calling persons to the

telephone for conversation. We decided to use magnetos and alternating current bells. Fig. 169 shows the essential mechanism of the bells. The bell at each end of the line consists of two gongs a, b and a' b', with a hammer c, c' between them. This hammer is attached to an iron armature h, h', pivoted over the electro magnets, m, m', in such a way that it rocks back and forth when an alternating current passes through the lines d e, f g. The bells at both ends of the line always ring together, since they are connected in series. A magneto (Fig. 170) is situated at each end of the line. This,

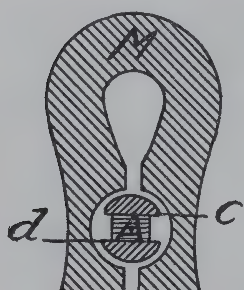


Fig. 170

as has been previously explained, is a generator of electricity, in which the field is furnished by steel magnet, *M*. The armature *A* is a coil of wire whose ends are in contact with the leading out wires *d* and *c* by means of brushes which slide upon rings. The armature is revolved by hand. The crank and cog wheels employed to produce high speed are not shown in the figure. By turning the armature rapidly this magneto will develop 60 volts e. m. f. on open circuit. The magnets of the bells are wound with a very large number of turns of very

fine wire, so that .025 ampere is sufficient to ring them.

Figure 171 shows how the magneto at either end of the line is introduced into the circuit for the purpose

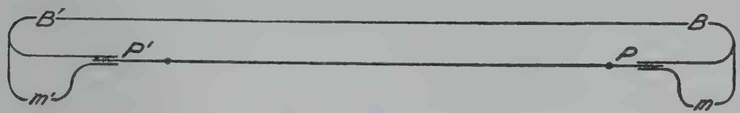


Fig. 171

of ringing the bells. B and B' represent the bells, m and m' the magnetos, and P and P' represent switches. Springs push them upward so that they normally close the circuit through the bells. When a person at P wishes to call another at P' he pushes the switch P down so as to bring his magneto m into series with the bells. When now he turns the crank and generates the electric current, both bells ring. His own bell serves the purpose of telling him that the line is operating all right. The other bell calls the party desired for conversation. As soon as the operator removes his finger from the switch P the spring throws it upward again, leaving his bell in circuit, so that he may be called at any time, but cutting out of the circuit his magneto, which would introduce unnecessary resistance.

The same wires which carried the current for

ringing the telephone bells carried also the current for operating the telephone receiver. When the receiver is removed from the hook it releases a twofold switch. This serves the double purpose of closing the primary circuit through the local battery and substituting the telephone receiver circuit for the bell-ringing circuit upon the line.

We used fifty chestnut poles to carry our line between the mill and the cottage. Each pole had a cross bar, on one end of which the electric light and power wires were carried and on the other end the telephone wires. Glass insulators prevented the wires from coming in contact with the wood of the cross bars. The necessity for this was impressed upon the boys by something which happened while they were stringing the wires. The telephone apparatus at the mill had been installed and the two leading out wires had been connected to it. One of these was coiled up on the floor, while the other had been strung along upon the poles for half a mile, but had not yet been attached to the insulators on the poles. While the boys were lunching at the mill, one of them gave the crank of the magneto a turn, when, to the astonishment of all, the bell rang. The circuit had been completed through the damp wood of the mill, through the damp wood of

some of the poles, and through the earth. After lunch the wire, so far as it had been strung, was fastened to the insulators upon the poles. But when some one turned the crank of the magneto the bell still rang. We walked along the line to see where the difficulty was. We found the end of the line about half a mile from the mill dangling free from the ground, but touching a tall spear of grass. When this was moved away from the spear of grass the magneto could no longer ring the bell. The slight current required to ring this bell —.025 ampere — had found its way through the spear of grass, through the woodwork of the mill and through the earth.

We had no sooner got the two telephone wires properly strung and attached to the hundred glass insulators when a thunder storm came up, and drove us back to the mill for shelter. Pretty soon the bell rang and we, supposing that some one at the cottage was trying to call, went to the instrument, but could get no response, nor could we make the bell ring. Lightning had sent an alternating current over the line which rang the bell, but the strength of the current was too great for our coils of fine wire and one of them was burned out, as we say. In other words, the wire

had melted at the point where it offered the greatest resistance.

The burned-out coil was replaced, and then we installed lightning arresters which were of two kinds. The first were simply fuses which were introduced into the line to protect it against any current too large for the apparatus to carry, and the second was a plate, *c* (Fig. 172). These are to be found upon the top of the magneto cases. A wire is connected with *c*, and its other end is grounded by being connected with a piece of iron pipe which is driven deep into moist earth.

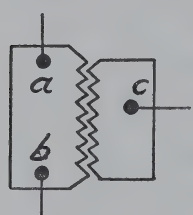


Fig. 172

The plate *a b* is inserted in the line, and the gap between this and the plate *c* offers sufficient resistance so that the telephone circuit suffers no leakage at this point, but lightning has such extremely high tension that it readily passes across this gap and finds its way to the earth without damaging the instruments.

We have already noticed that our alternating current dynamo, which produces 60 vibrations per second in the telephone receiver, causes it to give a tone very nearly like the *C*, which is two octaves below middle *C* upon the piano. *C* requires 64 vibrations per second. We may speed up our

dynamo so as to make it yield a tone exactly like *C* or even above it.

Dr. Cahill of Holyoke, Mass., has devised an organ in which alternating current dynamos produce the necessary number of vibrations for each tone. The name *telharmonium* has been proposed for this organ. It has a separate dynamo for each tone, each dynamo having a frequency corresponding to the tone required of it. The dynamo, for instance, which produces middle *C* makes the electric currents surge back and forth 256 times a second, and this causes the diaphragm of a telephone receiver to vibrate 256 times a second, and this sends forth 256 air waves per second, and when these reach our ears we recognize the tone we call middle *C*. The frequency of alternation in a dynamo may be increased by either increasing its speed of revolution or by increasing the number of coils upon its armature.

Mr. Cahill's great organ looks like a large machine shop with many countershafts geared so as to run at different speeds. On each shaft are a large number of little dynamos whose armatures have various numbers of coils. The organist, who may be far removed from this "machine shop," fingers an ordinary keyboard. Each key opens and closes a switch, thus bringing into action its own dynamo.

If the key which is known as *C*, one octave below middle *C*, is pressed down, a switch closes the circuit between the telephone and a dynamo which gives 128 double alternations of current.

The tone which is produced by 128 vibrations per second is the one most often heard from a man's voice in ordinary conversation.

Another key brings into action upon the same telephone receiver — and at the same time if desired — a dynamo which gives twice as many alternations per second and produces the tone most often heard in female conversation. It is middle *C*.

Another key might bring into action a dynamo which gives 64 vibrations per second to the diaphragm of the telephone receiver. This would send forth a tone very nearly like the base note of our 60-cycle alternating current dynamo.

The following table shows a series of ten tones which might be produced by the same little piece of sheet iron in a telephone receiver played upon by ten dynamos at the same time. The whole list of ten tones would sound well when produced simultaneously. The great mystery is that the iron disc can vibrate in such a complex manner. It is important to note, however, that the number of

vibrations in each of the upper tones is a multiple of that of the lowest tone:

2nd octave above Middle C	C″—1024	(= 16 × 64)
	G′ — 768	(= 12 × 64)
	E′ — 640	(= 10 × 64)††
1st octave above Middle C	C′ — 512	(= 8 × 64)
	G — 384	(= 6 × 64)
	E — 320	(= 5 × 64)
Middle C	C — 256	(= 4 × 64)†
1st octave below Middle C	G — 196	(= 3 × 64)
	C′ — 128	(= 2 × 64)
2nd octave below Middle C	C″ — 64	(= 1 × 64)*

* The tone most easily reproduced by the vocal cords of a man.
† The tone most easily reproduced by the vocal cords of a woman.
†† The tone which the telephone receiver responds to most readily.
The table covers the range of the human voice, male and female.

All the intermediate tones, with their sharps and their flats, are produced each by its own separate dynamo.

The insignificant amount of current required to operate a telephone receiver makes it possible to furnish the music of these dynamos to many and far distant telephones. This naturally suggests the idea of having a great musician perform upon the keyboard and have many auditors scattered about the city in their private homes or even in many public halls, for the telephone receiver can readily be made audible to a good-sized audience.

XVII

ELECTRIC BELL OUTFIT FOR THE COTTAGE

THE boys asked me what arrangement of electric bells we needed at the cottage and so I gave them this problem to work out by themselves:

1. We want a bell in the kitchen to be rung by a push button at the front door. But there are times when no one is in the kitchen and hence,

2. We want a bell upstairs to make a single stroke whenever the kitchen bell is rung from the front door.

3. We want a floor push under the dining-room table which will cause the kitchen bell to ring a single stroke.

4. We want a push button in the dining-room which will cause both bells to clatter and call people from their beds, from the piazza, the lawn, etc., to their meals.

This equipment needs only one battery of two dry cells, two bells, three push buttons and about two hundred feet of wire. It should cost less than five dollars.

The boys drew many plans and tried many schemes and at last determined upon the plan shown in Fig. 173.

P is the floor push under the dining-room table. When the circuit is closed at this point the current leaves the battery from the carbon pole *c*, passes up and around the magnets of the kitchen bell and back to the zinc pole of the battery *z* by way of the push button *P*. All other circuits are open.

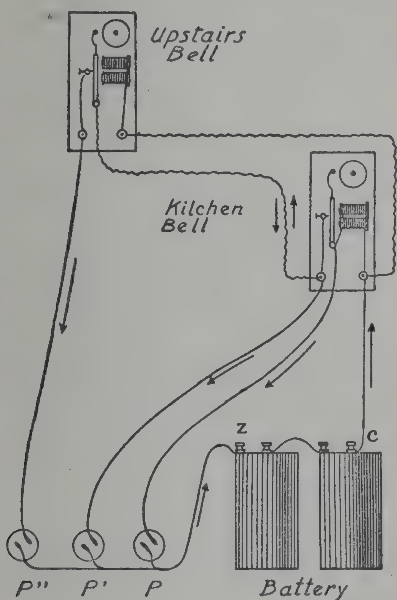


Fig. 173

P′ is the push button at the front door. When the circuit is closed at this point the current leaves the battery at *c*, passes up to the right-hand binding post of the kitchen bell and divides, part going through each bell. The portion of the current which goes through the kitchen bell passes around the magnets and through the armature to the left-hand binding post before it can find a path back to the battery.

Hence, the kitchen bell clatters. The portion of the current which passes to the upper bell goes around its magnets and finds a path back from the middle binding post to the battery by way of P'. Hence the bell upstairs rings with a single stroke.

P'' is a push button situated upon the wall by the side of the door which leads from the dining-room to the kitchen. When the circuit is closed at this point, the current leaves the battery at c, passes up to the right-hand binding post of the kitchen bell and divides, part of it going through each bell. The portion which goes through the kitchen bell passes around its magnets and through its armature to the left-hand binding post, then up to the middle binding post of the upper bell, through its armature to its left-hand binding post and back to the battery by way of the push button P''. The other portion of the current passes directly up to the right-hand binding post of the upper bell, around its magnets, and through its armature to its left-hand binding post, thence back to the battery by way of the push button P''. Hence, both bells clatter and keep time with each other. The upper bell will ring independently of the lower bell, but the lower bell is dependent upon the upper one to open and close its circuit, somewhat as a relay.

Soon after the cottage had been equipped with electric bells I went to the mill one day and found a push button at the door. Upon going in I was curious to examine the electric bell outfit of that place and found what is illustrated in Fig. 174.

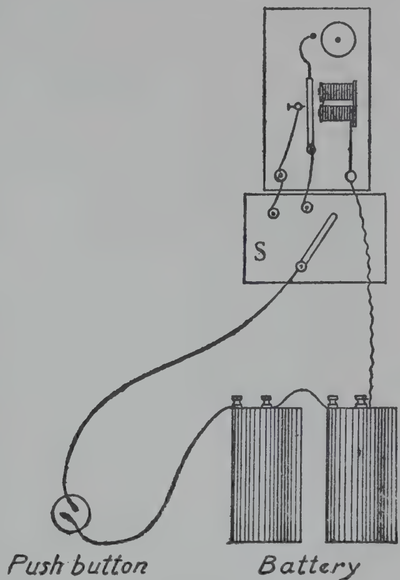


Fig. 174

A switch, *S*, had been attached to the bell. The boys said that when they felt well they kept the switch upon the left-hand point and the bell rang as a clatter bell. When they felt a little sick they put the switch upon the middle point and the bell rang with a single stroke, but when they felt very sick they put the switch upon the dead point and the bell did not ring at all.

XVIII

ELECTRIC WAVES

MUCH has been said about bringing young people up to do what they don't like to do so as to make them strong and virtuous. My own life has always been guided by a different principle. It is: *Find something worth while which you will enjoy doing, and do it with your might.* I am bringing up my boy on the same principle. In September we have a real desire to get back to our work in the city, and in June we have an eager longing for the occupations of Millville. I am not aware that there is any part of my work which I would like to be relieved from, and Harold and his mother said that they were now ready to return to the city apartment with real pleasure for a winter.

One evening we were seated about the dinner table when Harold asked me how electricity could travel without wires. I replied, "It travels as light does. But I am very much puzzled to know why it ever follows a wire when light does not."

This did not settle the question and left us both unsatisfied, so I told him to invite two or three of his best friends in to-morrow evening, and I would perform some experiments for them that would at least help them to think further upon this subject.

When the evening came I showed the boys an automobile spark coil to which I had attached two knobs, *a* and *b* (Fig. 179), and with which I had con-

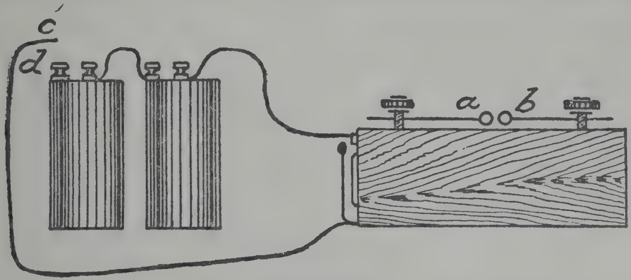


Fig. 179

nected two dry battery cells. When I touch the wire *c* to the binding post *d* a spark passes between the knobs *a* and *b*. When this spark occurs at least four kinds of waves pass out in all directions from the spark gap between the knobs.

First, sound waves go through the air. Our ears detect these. If the air is removed from around the apparatus no sound wave can go forth. A careful examination of the internal ear shows us that it is constructed so as to respond to such air waves.

Second, light waves go forth. These affect our

eyes. We are blind to the first kind of waves and deaf to the second. The light waves travel without air — somewhat better without air than with air. A microscopic examination of the eye indicates that it is constructed so as to respond to waves. We believe there are waves in the ether which fills all space. Sound waves travel in air at the rate of one mile in five seconds. We had this nicely illustrated at the sea shore one summer. The steamer touched each morning at a wharf which we could plainly see two miles distant. We could see the steam arise when she blew the warning whistle, and with our watches we found that it always required ten seconds for the sound to reach us after we saw the steam of the whistle. This at least showed us that it takes five seconds longer for sound waves to travel a mile than it does for light waves to travel the same distance. For light had to travel the same distance before we could see the steam arise from the whistle. Although the time it takes for light to travel a mile is inconceivably small, we have a simple method of finding out that it requires eight minutes for light waves to come to us from the sun.

The satellites of the planet Jupiter, in revolving about that body, disappear and reappear at regular intervals, acting as flash lights to mark time.

The earth, being 92,000,000 miles distant from the sun, is 184,000,000 miles farther from Jupiter when at *B* than it is when at *A*. (See Fig. 180.) It is found by observation that sixteen minutes more are required for the light waves from a reappearing satellite to reach us at *B* than when we are at *A*. Hence eight minutes would be required for light waves to travel the distance from the sun to the earth. Although light travels at the inconceivable velocity of 186,000 miles per second, the nearest star is so far distant that it takes light three and a half years to come from it to us. The North star requires forty-two years to send its light to us, and Arcturus is so far away that waves of light sent out from it one hundred and sixty years ago are only just reaching us now, and if it should cease to send forth light

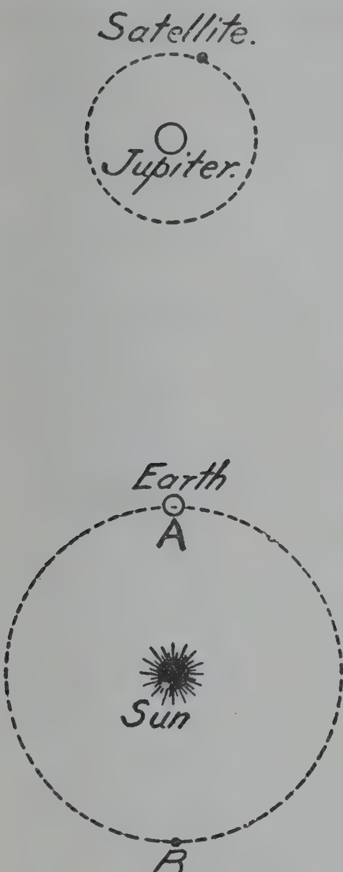


Fig. 180

now men would continue to see it for five generations yet to come.

A third kind of wave which goes forth in the ether from the spark gap of our coil is a heat wave. This affects neither our eyes nor our ears, but I will undertake to make you conscious of it by another method.

Before a mixture of gasolene vapour and air can be ignited its temperature must be raised to about 2000 degrees Fahrenheit. I will show that heat waves pass out from this spark gap by placing my watch crystal filled with gasolene underneath the knobs of the spark coil, (Fig. 181). When now I close the electric circuit at the battery the mixture of gasolene vapour and air just above the watch crystal is ignited. If I increase the distance between the knobs you still hear the crackle of the sound waves and see the light waves, but the mixture of gasolene vapour and air does not ignite, because there are not heat waves enough. The automobilist expresses this fact by saying a "fat" spark or a "warm" spark is needed. A battery which has ceased to give a sufficiently hot spark to explode the mixture of gasolene and air in the cylinder of a gasolene engine may serve all other

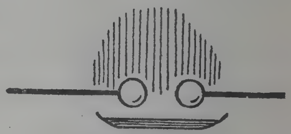


Fig. 181

purposes quite as well as ever. It may ring bells almost as long as it ever would.

I proved that the temperature for igniting a mixture of gasolene vapour and air was nearly as high as melting iron, by heating an iron rod to a dull red heat and bringing it to the watch crystal containing gasolene. It did not take fire. I showed that it could not be ignited by a lighted cigar, nor even by a glowing coal taken from the fire.

It was necessary to heat the iron rod to a very bright red heat — nearly white heat, or nearly to its melting point, before it would ignite the mixture.

These heat waves are ether waves, differing from light only in having greater wave length. They travel at the speed of light, they travel better without air than with air. They come from the sun and all other light-giving bodies. Indeed, an ordinary incandescent electric lamp gives out about twenty-four times as much energy in heat as in light. Heat waves are being thrown off from all bodies which are around us. The steam radiators are placed in this room for the express purpose of sending out heat waves through the ether in this room. This is the chief method of distributing heat, and it is hindered rather than helped by the presence of the air. The walls, ceiling, floor,

furniture, people — everything here is sending out heat waves.

The fourth kinds of waves, which go out from the spark gap of our coil, are also waves in the ether. They are still longer than heat or light. We have ears for sound, eyes for light, and temperature sensation for heat, but as yet we have not evolved a delicate sense organ for detecting electric waves. At least few of us claim to have such a sense. I will, however, undertake to make you feel electricity. I then adjusted the coil so that each boy might take a mild electric shock from it by touching the two knobs. That is by placing himself in the spark gap. They agreed that although they could not hear, see, taste, or smell electricity they were a little more familiar with it now, having felt it.

Sound waves in air, as given out by the piano, vary in length from, say, four inches to forty feet, those having the shorter wave length being the higher pitched tones.

Light waves in the ether, as given out by the sun, vary in length from, say, $\frac{1}{60000}$ to $\frac{1}{30000}$ of an inch, those having the shorter wave length being the violet-coloured light, which may be seen in the rainbow, and those having the longer wave length being the red-coloured light of the rainbow or the sunset.

Heat waves, which are also waves in the ether, vary in length from above $\frac{1}{30000}$ to, say, $\frac{1}{6000}$ of an inch. Roentgen or X waves are ether waves, shorter than light; while Hertzian, or wireless telegraph waves are very long ether waves, varying from a few feet to many rods in length. Those used by Marconi in sending despatches across the Atlantic Ocean are as long as 1000 feet, four or five of them cover a mile, and 12,000 of them cover the whole distance from Cape Cod to Poldhu.

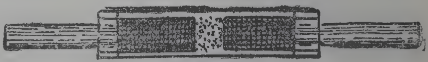
Electric waves are easily broken up into the shorter heat waves, or the still shorter light waves. On the other hand Roentgen waves are readily transformed into the longer light waves, and are thus brought within our powers of vision.

Sound waves of various lengths (of high and low pitch) all travel at the same speed (one mile in five seconds), else how would the piccolo and the bass horn of the distant band sound together. So ether waves of various lengths (light, heat, electricity, etc.) all travel at the same speed, *i. e.*, 186,000 miles per second.

For detecting the electric waves which may be sent out from the spark gap of our automobile spark coil I shall ask you to help me prepare a special piece of apparatus. One boy may file this silver

ten-cent piece and another may file this nickel five-cent piece, each gathering the filings upon a piece of paper. A third boy may select a piece of glass tubing about one eighth of an inch in the inside diameter, and with a three-cornered file cut off a short piece, about one and a half inches long, and smooth the ends with a wet file. A fourth boy may select a piece of stout copper wire nearly as large as the bore of the glass tubing, and cut from it two pieces, each about two inches long. Wind one end of each of these with thread to make them fit snugly in the glass tubing.

We thrust one of the wires into the tube, then mixed equal parts of the silver and nickel filings and put as much of the mixture into the tube as we could hold upon the tip of a penknife blade, and then thrust in the other copper wire. (See Fig. 182.) The ends of the wire were about one eighth of an inch apart and the gap was loosely filled with the metal filings. This was connected by short pieces of copper wire, as shown in Fig. 183, to a dry battery cell, *B*, and a sensitive ammeter. When all connections were made the needle of the ammeter remained at zero, showing that no electric current was passing,



Coherer

Fig. 182

that is, the battery cell was unable to send any electricity through the metal filings.

This is the apparatus which is to help us detect electric waves when they pass about us. Electricity has been called invisible light, that is, invisible to our eyes, and this apparatus has been called an "electric eye" because it will detect electric waves in the ether, just as our eyes may detect light waves passing through the ether.

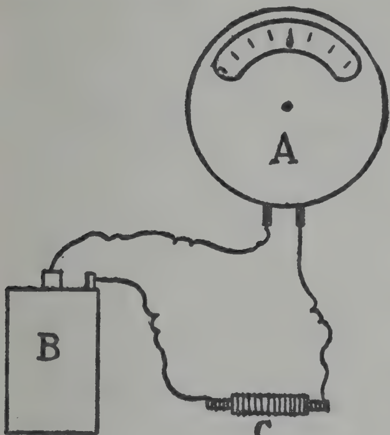


Fig. 183

We placed the automobile spark coil upon the table near to the tube containing the filings of silver and nickel, and as soon as we made a spark pass between the knobs the ammeter needle moved half way across the scale, indicating that the spark had somehow influenced the metal filings in the tube so that now they permitted the battery cell to send some electric current through them and through the ammeter. I asked one of the boys to tap the tube slightly with a lead pencil so as to jar

the metal filings, and as soon as he did so the needle of the ammeter went back to zero.

The spark coil sent electric waves out in every direction, and those which hit the metal filings made them cohere together. In that condition they allowed the dry cell to send through them enough current to move the needle of the ammeter. Tapping the tube made the metal filings break apart again, in which condition they do not allow the current of the cell to pass in sufficient quantity to move the needle. This tube is called a *coherer*, because the filings in it cohere together. The apparatus then serves to indicate when electric waves are passing. As yet, however, it would not respond when the spark coil was more than one foot away. Our next step was to attach extra pieces of wire, each ten or twelve feet long, at either end of the coherer, as indicated in Fig. 184. One of these wires was stretched out upon the floor while the other one was connected with the wire of a picture hanging upon the wall.

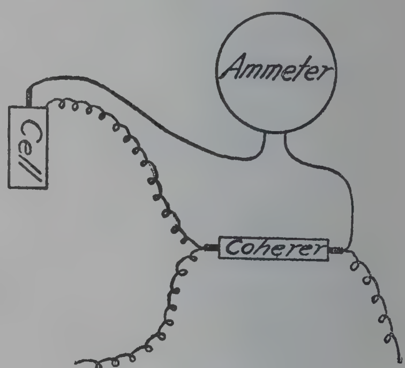


Fig. 184

We now found that the coherer would respond when the spark coil was operated several feet away. The extra wires which we had attached to the coherer are called antennæ, because they suggest the long "feelers" or antennæ of some insects.

Our next step was to put antennæ upon the spark coil also, as shown in Fig. 185. One of these wires

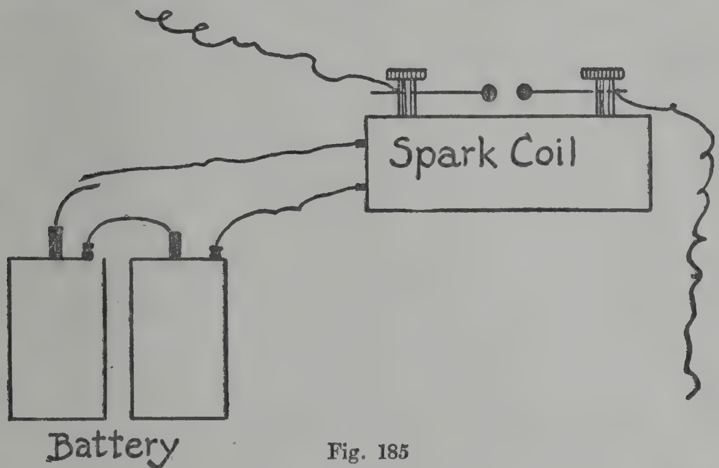


Fig. 185

was stretched out upon the floor, while the other one was connected with the wire of a picture hanging upon the wall on the opposite side of the room from where the coherer was. We now found that the coherer would respond when the spark coil was operated in the farthest part of the room. With the wires which were lying upon the floor extending toward each other, but lacking several feet of touching

the coherer responded when the spark coil was operated in various other rooms of the house, although the doors between were shut. When the floor wires were connected to the water pipes the coherer would respond when the spark coil was operated in a neighbouring house. We tried a similar experiment, substituting an ordinary electric bell for the spark coil. The coherer or electric eye detected that ether waves were sent forth from an electric bell every time a spark was produced in the bell. For this purpose connections were made, as shown in Fig. 186. One dry battery cell was used to ring the bell. The floor wire *a*, or, as it is usually called, the ground wire, was connected to the binding post 1, and the other antenna was connected to the screw 3, and then supported aloft on a picture hung upon the wall. With this transmitter we sent waves across the room which were detected by the coherer.

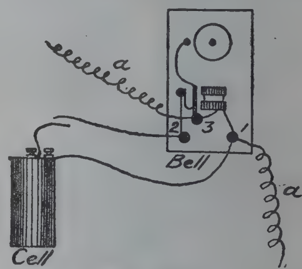


Fig. 186

We constructed a simple spark coil as follows: We bought a pound of No. 24 single cotton covered copper wire, such as is used in the electro magnets of bells. It was, when we bought it, wound upon

a wooden spool. We filled the hole in the centre of this spool with wire nails. One dry cell was connected with this (Fig. 187). When the wires at *d* were touched together, and then separated, a spark was produced at that point. A ground wire was connected at *b*, and an antenna at *c*, as before. Using this apparatus now as a transmitter of ether waves, we found that the coherer detected them.

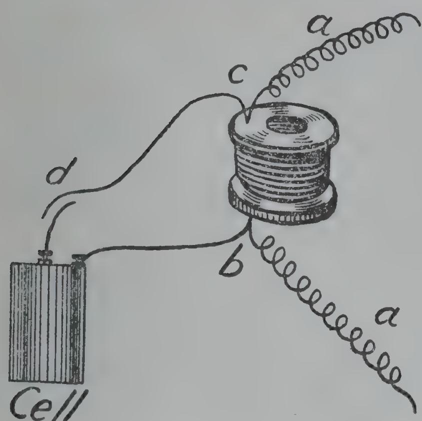


Fig. 187

We next gave our attention to making changes in the receiving apparatus, not to change the coherer, but to provide substitutes for the ammeter. A sensitive *relay* was procured, which is essentially like a bell or buzzer except that it does not clatter. It will be readily understood, by referring to the accompanying Fig. 188, that *R* is a coil of insulated wire around an iron core exactly like what we see in the electric bell. (In practice there will be a pair instead of one of them.) Such coils are called electro magnets, because when electricity flows in

the wires they become magnets, and will attract iron. *A* is an iron spring, *B* is a dry battery cell and *C* is the coherer. Whenever an ether wave passes the coherer permits the battery cell to send a current around the magnet of the relay, and it attracts the iron spring *a*, so that it hits against the metal post *d* with a click. Whenever we used this to respond to ether waves the click of the relay suggested the telegraph sounder. How it served in wireless telegraphy will appear in the following pages.

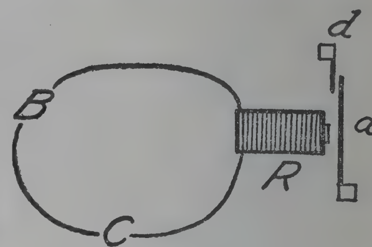


Fig. 188

XIX

RINGING BELLS AND LIGHTING LAMPS BY ELECTRIC WAVES

HAROLD was to have a birthday party, to which many of his school friends were invited. For this occasion he prepared, with my help, to perform for the girls and boys some electrical experiments, and particularly to give all who chose to try it an electric shock. For this purpose he had them all join hands, and the electric charge was sent through the whole line at once. One thing he did shocked his mother more than anything else. He instituted a mock court, at which one of the boys was tried, convicted and condemned to be executed by electricity. The whole affair was enacted with no great solemnity, but the electrical experiment was voted a great success by the executed "criminal." The following group of experiments, however, seemed to give the most satisfaction: On a table was placed the coherer connected to the relay, and in another room was placed the spark coil for sending ether waves.

He had this operated by a confederate whom he chose for the purpose. He then connected two wires to the relay, one at *d* and the other at *e* (Fig. 189). These ran to a battery cell and a bell

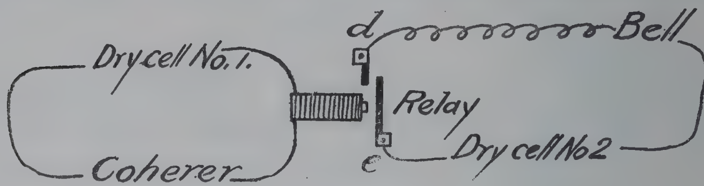


Fig. 189

in a far corner of the room. At a given signal (a cough) the confederate made a spark at the spark coil in the other room; this sent ether waves through the partition between the rooms; the ether waves caused the coherer to pass electricity from the dry cell No. 1, to close the relay spring *R*. This acted like a switch to close the second circuit through the dry cell No. 2 and the bell, which rang out to the surprise of all. It continued to ring until he tapped the coherer tube and broke apart the filings. When this had been tried to the satisfaction of all, the company was invited to another room. Here they found an electric train with tracks, train sheds, stations, tunnels, bridges, switches, signals, etc., arranged upon a centre table. The electric train was to be started by ether waves. A wire from the railroad track was connected with *e* of the relay

(See Fig. 190). A wire from *d* of the relay was connected to the third rail through a battery of sufficient strength (Battery 2). The electric train completed the circuit by connecting the tracks with

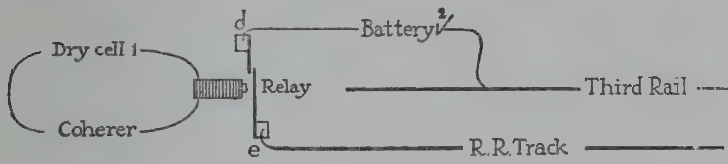


Fig. 190

the third rail. All heard the crack of the spark coil in the adjoining room, and saw the train start immediately. Ether waves had caused battery 1 to close the relay *R*. This had closed the circuit so that battery 2 might run the train, of course by means of a motor in the train. He tapped the coherer. The relay spring *R* flew open and the train stopped. Presently another crack from the adjoining room, and the train instantly started again. When all the details of the electric train had been examined the company was invited to go to the dining room, which was dimly lighted by candles. All were seated and busily conversing when the crackling noise of the spark coil was again heard, and a group of little electric lights flashed forth upon a birthday cake. The wires from the lamps and a battery to run them

had been connected with the binding posts *d* and *e* of the relay.

The chandelier over the dining-room table had a pendant push button *A* (Fig. 191), with which the regular electric lights could be turned on and off. This I had removed and extended the wires down upon the table. It was only necessary to connect these to the binding posts *d* and *e* of the relay, and the next wave from the spark coil lighted the chandelier.

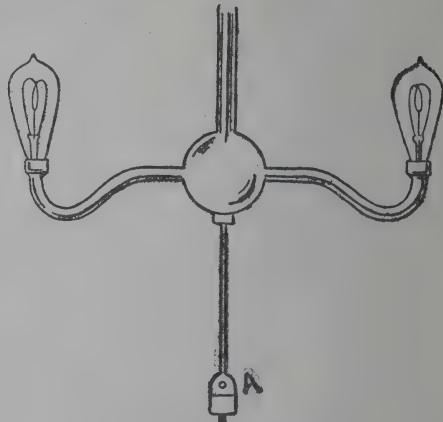


Fig: 191

The flexible wires underneath the dining-room table with which the maid is usually summoned from the kitchen were next extended up and connected with *d* and *e* of the relay, and the maid was called in by an ether wave. She brought with her a tray in the centre of which stood an earthenware cup, such as is used for baking custard. This had been filled with a mixture of granulated sugar and powdered potassium chlorate. Four dry battery cells stood around this upon the tray connected in series

(Fig. 192). A very small iron wire connecting two of these cells dipped into the sugar mixture. Two wires from the battery were connected to *d* and *e* of the relay. At the proper signal an ether wave was sent out by the spark coil. The coherer closed the relay and the relay acted as a push button to close the circuit of the four cells upon the tray. The fine wire dipping into the sugar and potassium chlorate got red hot. This caused the mixture to flash up and burn in most beautiful coloured flames. (Fig. 193).

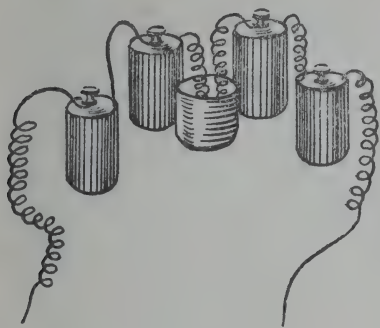


Fig. 192

On this occasion Harold's friends gave him, with due formalities, the degree of E. E., which they said meant *electrical expert*, and ever since that night he has been called "the expert." I inquired of the young folks, as their party was breaking up, if they understood Harold's explanations of all these things, and he replied that he at any rate understood them better having attempted to explain them.

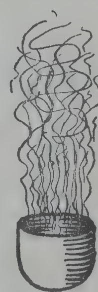


Fig. 193

XX

TELEGRAPHING BY ELECTRIC WAVES

THE next time Harold and I experimented we arranged something to save us the trouble of tapping the coherer each time we used it. We employed simply an electric bell, *B* (Fig. 194), from which we removed the gong. By reference to the figure the arrangement will be understood. Each time ether waves cause the metal filings to cohere and the battery B^1 closes the relay *R*, battery B^2 causes the hammer of B^3 to tap against the coherer. This causes the current to cease to flow from B^1 and the relay opens again by its own spring.

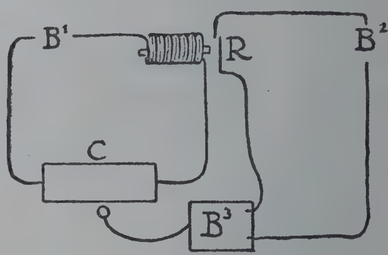


Fig. 194

Our next addition was a telegraph sounder as shown in Fig. 195. B^1 is a single dry cell, *C* is the coherer, *R* is the relay, B^2 is now a battery of three cells. Part of its current goes to B^3,

Photograph by Helen W. Cooke

Induction Coil of a Wireless

the tapper for the coherer, and part of its current goes to the electro magnet of the telegraph sounder *S*. Ordinarily a spring holds the iron strip *d* up

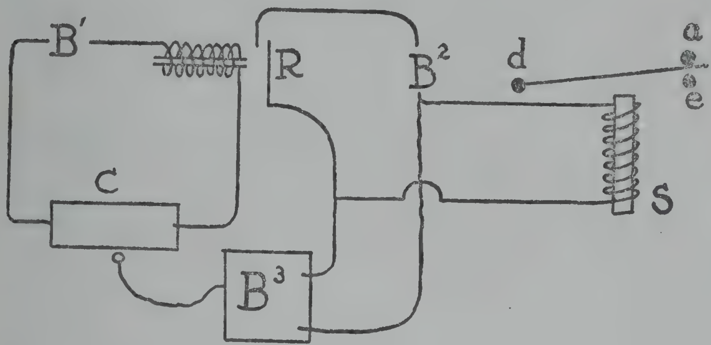


Fig. 195

against the metal stop *a*, but when the current passes through the electro magnet it pulls down this iron strip with a click against the metal stop *e*. But while this is happening *C* is being tapped by *B*, and is ready to respond to each wave. It was only necessary now to have some code of signals in order to communicate by telegrams. We learned the system of dots and dashes, or short and long periods marked off by the sounder, which all telegraphers use and which is known as the Morse alphabet, and very soon Harold and I were telegraphing from one room to another messages of several sentences at a time, the Morse alphabet

being told off on the spark coil and being received through the coherer and telegraph sounder. It was not long before Harold and one of the neighbours' boys were exchanging messages between their homes, each having a spark coil and the necessary receiving apparatus, and having extended their antennæ to the top of the buildings into what are called in the wireless language *aerials.*

The fever for wireless telegraphy spread like wildfire among the boys. In a few months they had formed a "wireless club." They had each read anywhere from ten to thirty books and articles upon the subject, and had secured the latest improved apparatus. They made it a practice to spend hours daily at their instruments picking up and keeping on file messages which were sent to and from steamers leaving the harbour for European ports. On one occasion they showed me from these files scores of messages — fond, personal, and supposedly private farewells to friends and communications between business partners which they would never have made on land without first closing the office door. The boys had acquired a mass of technical knowledge upon the subject which far exceeded my comprehension. But their teachers in school complained that they would learn nothing

else, and some of the boys had already received warning that they might fail of promotion.

How to have compelling interests without riding hobbies is the great problem for both boys and men. I have known many boys who could, or at least would, do nothing well in school or out, except some specialty like manual training or science. In later years they were so deficient in education that they could hold no worthy position in anything. My anxiety was to save my boy from such a fate. I was determined that he should have a fair share of all kinds of culture. To this end we read together much of biography, history and classical literature, ancient and modern, through the medium of the English language.

As both prevention and cure of the wireless telegraph mania I deemed it not necessary to suppress enthusiasm, nor to introduce obviously useless tasks for the sake of the training which might be in them. My method was, on the contrary, to encourage my boy to have several hobbies which he might ride with enthusiasm, but to make it a rigorous rule to exchange his "mount" occasionally.

XXI

WIRELESS TELEGRAPHY IN EARNEST

WE HAD decided to let Harold make a trip to Europe alone. The first message from him after his departure was a brief note to his mother saying that they had had a turbulent voyage, but all had landed safely upon the other side, none the worse for their experiences.

The next day a number of letters came to me from total strangers. One of these ran as follows:

MY DEAR SIR:

Prompted by my own impulses, and urged to do so by the passengers under my charge, I improve this first opportunity to express to you our high appreciation for your noble but very modest son, to whom more than to any one else we owe the lives of all on board our fated ship.

I am sending this direct to you both, because I understand a father's heart and because the young man escaped as soon as we came to land, without any of us learning his address. I beg you will communicate to him the desire of the president of our company to meet him and personally to thank him for his gallant conduct. I am also instructed to say that whenever Harold desires to cross the ocean the best which any ship I may command can afford will be his without charge.

Very respectfully yours,
——— Captain.
S. S.

Another letter was the following:

My dear Sir:

Permit me to congratulate you on having such a heroic and self-possessed son. We, his fellow passengers, are, if possible, as proud of him as you must be.

I fear that his account of the affair will not do himself full justice, and so, with your permission, I will give you the full details as I have gathered them from the passengers, from the crew, and from my own observation.

During the last night of our voyage a thick fog closed about us. The constant blowing of the fog whistle made the night dismal. Few persons slept at all. About two o'clock in the morning the ship struck a reef, and instantly it seemed as though every person on that ship reached the decks at the same time. The water poured in and put out the fires. The ship heeled badly, and it seemed that any minute she might slip off the reef on which she was resting into deep water and go down. To add to our horror fire broke out. It seems to have started in the wireless operator's room.

Very much damage was done to the wireless oufit itself, and the operator was badly burned, so much so that he was taken to the ship's hospital suffering with many painful and dangerous wounds.

Meanwhile the flames spread rapidly and we were unable to summon help. The crew and many of the passengers fought the flames, but with little success.

In the midst of our despair word passed around the ship that an unknown boy from among the passengers was sending the C. Q. D. message to all the world by wireless. It was afterward learned that your Harold was the youth. He had repaired the damaged apparatus sufficiently to establish connection with a storage battery which he found, and, under the captain's direction, was sending forth that hurry call for help known to all the wireless fraternity and heeded by all seafaring men. I learned that your boy was not a regular operator, but that somehow he had learned to send this message and also to send out the captain's calculations of our position at sea. He was also able to detect that his call had been heard and that help was coming, although he could not understand much that came to his instrument in reply to his calls. I learned, also,

that he was one of the first to reach the operator's room and to give assistance. He was himself badly burned, so much so that one hand was being dressed by a nurse while he was continually using the other to operate his instrument.

I can testify, my dear sir, that he appeared to be the calmest and most self-possessed person on board that ship, as I saw him in the glare of the dreadful flames which lit up the blackest night.

I am an artist and would like to attempt to paint that scene, which has left its lasting impression upon my soul. I beg that you will allow me to exhibit it for a time in several of our galleries and finally present it to your family.

Help came none too soon. We were all transferred to other boats, but the sea was rising, and scarcely had we reached a safe distance when the burning ship slipped into the sea and disappeared.

I do not know by which boat your son reached the land. In the great confusion I lost sight of him at last. He has doubtless communicated with you by this time, and I shall esteem it a great favour if you will put me in communication with him again.

In order that I may do justice to him in the painting I would like to arrange with him a few sittings while he is in Europe.

Could you kindly send me a photograph of him which will assist me somewhat?

Most sincerely and gratefully yours,

———————————.

The letter contained several references to mutual acquaintances.

Harold's letters have been frequent and full of the pleasure he is having in European travel, but the only thing he has said about the voyage is that "it was not worth so much fuss."